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WASHINGTON GEOLOGICAL SURVEY.

HENRY LANDES, STATE GEOLOGIST.

VOLUME I.
ANNUAL REPORT FOR 1901.
IN SIX PARTS.

PART IV.

THE IRON ORES OF WASHINGTON.

BY S. SHEDD.

THE COAL DEPOSITS OF WASHINGTON.

BY HENRY LANDES.



OLYMPIA, WASH.,
GWIN BIGGS, . . . STATE PRINTER
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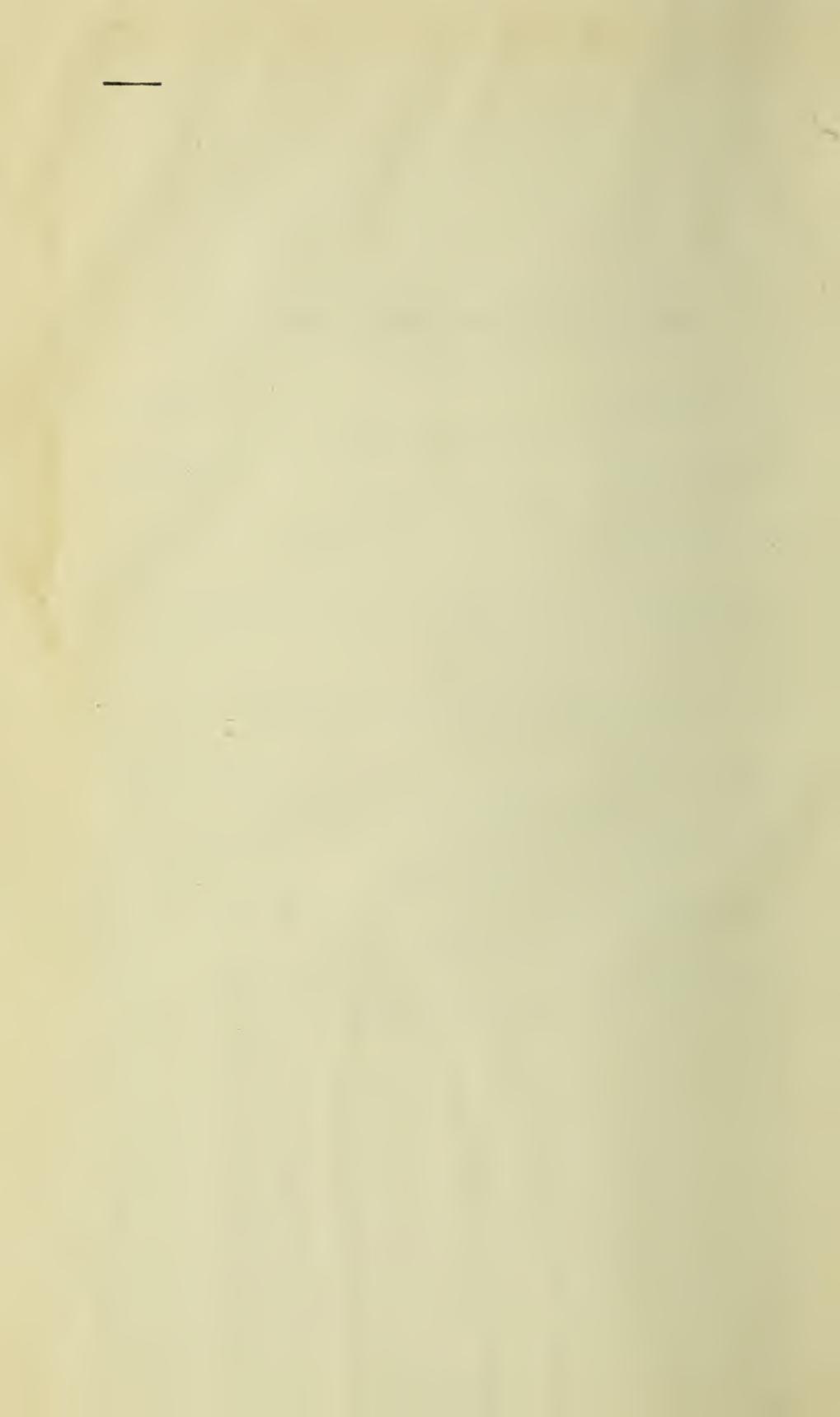
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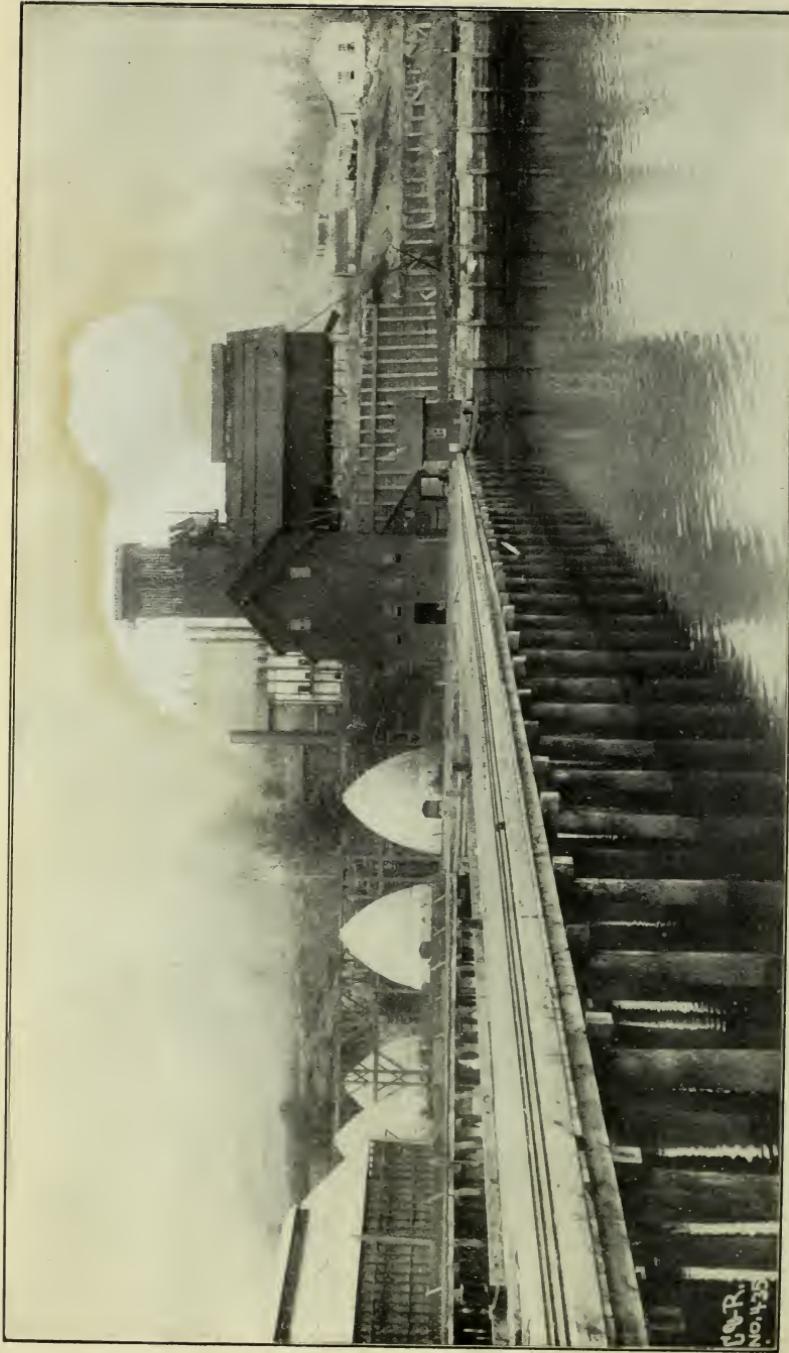
PREFACE.

In the IRON ORES OF WASHINGTON, by S. Shedd, the subject is treated more exhaustively than is the case with any other part of this report. A description is given of all the known occurrences of iron in the state, together with complete analyses and comparisons with ores found elsewhere. In the field work necessary to the preparation of the article on iron ores, two seasons were occupied by Professor Shedd and his assistants. The field work was all done prior to the inauguration of the State Geological Survey, and the entire expense of it was borne by the State Agricultural College and School of Science.

The article on the COAL DEPOSITS OF WASHINGTON, by Henry Landes, is a brief description of the coal fields and coal mines of the state. While the general geology of the subject is touched upon, along with the extent of the coal areas, etc., the commercial phase of the subject receives the most emphasis. At the present time coal constitutes by far the most important mineral resource of the state, and the treatment accorded it in this report is regarded as wholly inadequate. The present article is but a temporary treatment which it is planned to replace by a thorough and extended one a little later.



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PLANT OF PACIFIC STEEL COMPANY, IRONDALE.

THE IRON ORES OF WASHINGTON.

BY S. SHEDD.

NOTE.—The work of preparing this report on the iron ores of Washington was begun in the summer of 1899, under the direction of the Board of Regents and the president of the Washington Agricultural College and School of Science, and the entire expense, for the work, has been defrayed by the College. The summer of 1899 and a part of the summer of 1900 was spent in the field visiting the different localities, collecting samples, and studying the different deposits. The analyses of the Washington ores given herein, with the exception of those taken from a manuscript report by R. H. Stretch, E. M., and one from Willis and Smith's paper on the Clealum district, were made by myself or by the chemists of the department of chemistry in the Washington Agricultural College and School of Science.

While I take sincere pleasure in acknowledging the kind and ready assistance rendered me by those upon whom I had occasion to call for help or information of any kind, I am especially under obligations to Messrs. Thomas Cooper, J. J. Conner, Chas. Denny, and H. L. Blanchard for the interest shown and the help given, and I desire to express to them, especially, my most hearty thanks and appreciation of their kindness.

DISTRIBUTION AND COMBINATIONS IN WHICH IRON OCCURS.

GENERAL STATEMENT.

Iron is one of the most widely distributed of all the different minerals. It seldom occurs in the native state, but is combined with different elements, oxygen being the most common one, and in this form it is a very important factor in giving the color to the various rocks and soils. It combines with sulphur to form sulphides and is then known as iron pyrites and in this form it is very important, not for the manufacture of iron, but from the fact that it frequently carries more or less of the precious metals, such as gold and silver. Iron is also found in combination with other elements, such as phosphorus, silica, titanium, arsenic, etc.

THE ORES OF IRON.

While iron occurs in combination with many different elements, there are only a few forms that are used in the manufacture of iron. The valuable ores commercially are the magnetites, the hematites, the limonites, and the carbonates.

Magnetite is an anhydrous oxide of iron and when perfectly pure has the following per cent. of iron and of oxygen: Magnetite (Fe_3O_4) metallic iron, 72.4 per cent., oxygen, 27.6 per cent.

While theoretically magnetite should contain 72.4 per cent. of iron, practically very little of it does contain so high a per cent. on account of the impurities that occur with it. The common impurities are such minerals as quartz, feldspar and hornblende. Magnetites always give a black streak and differ in this respect from the hematites which have a red or brown streak. The magnetites also have the property of magnetism; that is, they are attracted by a magnet.

Of the different varieties of iron ores mined in 1899, only 1,727,430 long tons, or 7 per cent. was magnetite.*

Hematite is an anhydrous oxide of iron having, when pure, the following composition: Hematite (Fe_2O_3), oxygen 30 per cent., iron 70 per cent.

This is the most important ore of iron and is the most widely distributed of any of them, being disseminated in greater or lesser amounts in the soils and nearly all rocks; in fact most soils and rocks owe their color to iron. It is not confined to rocks of any particular geological age or to rocks of any particular kind. There are several different varieties of hematite, such as specular iron, red ochres and clay iron stone, but all of these varieties when pulverized give the characteristic red powder which distinguishes them from the other oxides of iron.

"The specular variety is mostly confined to crystalline or metamorphic rocks, but is also a result of igneous action about some volcanoes, as at Vesuvius. Many of the geological formations contain the argillaceous variety of clay iron stone, which is mostly a marsh formation, or a deposit over the bottom of shallow, stagnant water; but this kind of clay iron stone, that giving a red powder, is less common than the corresponding variety of limonite." (Dana, Edward S.: *Text Book of Mineralogy*, p. 335.)

In 1899 there was mined in the United States 20,004,399

*21st Ann. Rep. U. S. Geol. Survey, Part VI, Min. Res., p. 33.

long tons of red hematite, which is 81 per cent. of all the iron ore mined in the United States that year.*

Limonite, or brown hematite, is a hydrous oxide of iron having the following composition: Limonite ($2\text{Fe}_2\text{O}_3$, $3\text{H}_2\text{O}$) oxygen 25.7 per cent., iron 59.8 per cent., water 14.5 per cent.

This ore is a secondary product, in all cases, and is derived from the alteration of other ores, minerals or rocks containing more or less iron. The variety known as bog ore is the most widely distributed, occurring in many places in the United States. It has been formed in marshy places and has been carried in solution, by streams, into these places.

This ore is very apt to contain more impurities, such as silica, clay, phosphates, oxides of magnesium and other substances of this nature than magnetite or hematite. Limonite is distinguished from the other oxides of iron by its brown color when finely powdered.

The brown hematites, in 1899, amounted to 2,869,785 long tons, or 11.6 per cent. of all the iron ores mined in the United States for that year.†

Siderite, or spathic iron, is the protocarbonate of iron and has the following composition: Siderite (Fe CO_3) carbon dioxide 37.9, iron protoxide 62.1, metallic iron 48.2 per cent.

The spathic ores are the lowest in iron of all and are least important, as shown by statistics of production for 1899, there being only 81,559 long tons mined or .33 per cent. of the iron ore produced during that year.‡

The following table, taken from the Twenty-first Annual Report of the United States Geological Survey, Part VI, Mineral Resources, page 35, gives the amount of the different classes of iron ores mined in the United States for eleven years from 1889 to 1899, inclusive, with the per cent. of each class for the eleven years and also for the last year 1899. This table is given here for comparison and shows that the most important iron ore has not been found in Washington in anything but small quantities up to the present time.

* 21st Ann. Rep. U. S. Geol. Survey, Part VI, Min. Res., p. 32.

† 21st Ann. Rep. U. S. Geol. Survey, Part VI, Min. Res., p. 33.

‡ 21st Ann. Rep. U. S. Geol. Survey, Part VI, Min. Res., p. 33.

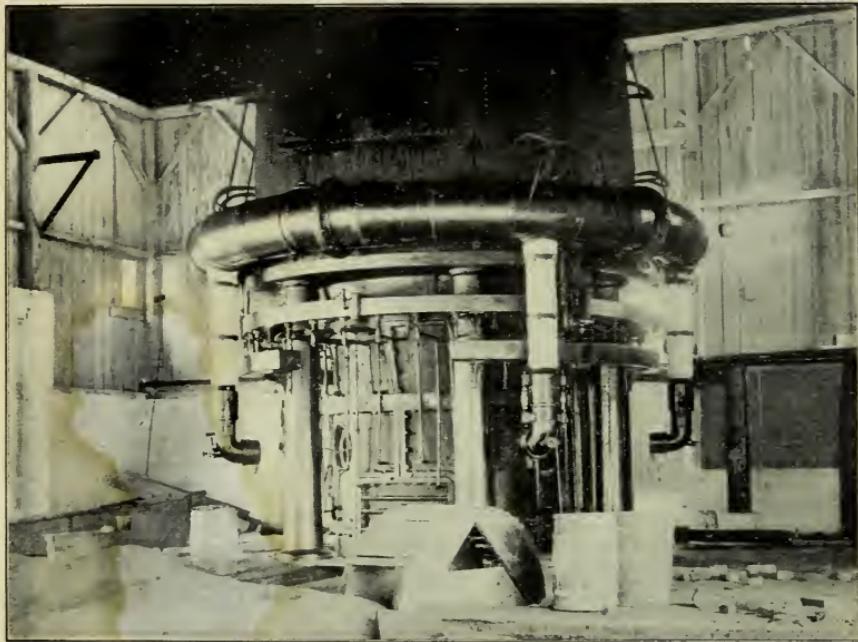
PRODUCTION OF IRON ORES IN THE UNITED STATES BY CLASSES.

YEAR.	<i>Red hematite, long tons.</i>	<i>Brown hematite, long tons.</i>	<i>Magnetite, long tons.</i>	<i>Carbonate, long tons.</i>	<i>Total, long tons.</i>
1889.....	9,056,288	2,523,087	2,506,415	432,251	14,518,041
1890.....	10,527,650	2,559,938	2,570,838	377,617	16,036,043
1891.....	9,327,398	2,757,564	2,317,108	189,108	14,591,178
1892.....	11,646,619	2,485,101	1,971,965	192,981	16,296,666
1893.....	8,272,637	1,849,272	1,330,886	134,834	11,587,629
1894.....	9,347,434	1,472,748	972,219	87,278	11,879,679
1895.....	12,513,995	2,102,358	1,268,222	73,039	15,957,614
1896.....	12,576,288	2,126,212	1,211,526	91,423	16,005,449
1897.....	14,413,318	1,961,954	1,059,479	83,295	17,518,046
1898.....	16,150,684	1,989,681	1,237,978	55,373	19,438,716
1899.....	20,004,399	2,869,785	1,727,430	81,559	24,683,173
Totals.....	133,836,710	24,697,700	18,174,066	1,798,758	178,507,284
Percentages of totals for eleven years	75.00	13.8	10.2	1.00	100.00
Percentages of total for 1899.	81.04	11.63	7.0	0.33	100.00

THE RELATIVE VALUES OF IRON ORES.

The value of an iron ore does not depend entirely upon the amount of iron it contains, but upon the other substances, and amounts of them, found with it. The most common injurious substances are phosphorus and sulphur. There are, however, a number of other substances that occur as impurities, such as titanium, silica, alumina, calcium, and magnesia. These latter, however, can hardly be considered as injurious substances in the sense of injuring the pig iron, but rather as lowering the per cent. of iron. They also determine the fluxes needed. Sulphur and phosphorus, however, act in an entirely different way, and even a small amount of either of these injures the ore for a Bessemer pig iron.

Again its location is an important factor in determining the value of an iron ore, so that an ore may be quite high in the per cent. of iron it contains and still not be of any value, simply because it would cost too much to get it to market. Then again the nearness of fuels and fluxes come in to regulate its value. Take for instance Pennsylvania, which ranks first in the product of pig iron, producing in 1899, 6,558,878 long tons, or about one half of the entire product of the United States for that year, but which ranks fifth in the production of iron ore. This comes from the fact that, while Pennsylvania does not have as large deposits of iron ore as some of the other states, she does have very extensive beds of good coal, and it has been found cheaper,



FURNACE, PACIFIC STEEL COMPANY, IRONDALE.



CHARCOAL KILNS, PACIFIC STEEL COMPANY, IRONDALE.

as a general thing to ship the ore to the fuel than to ship the fuel to the ore.

THE HISTORY OF IRON MINING AND MANUFACTURE IN WASHINGTON.

The first furnace for the manufacture of pig iron in Washington began operation in the fall of 1880. This furnace was located at Irondale on Port Townsend bay about four miles south of the city of Port Townsend. The furnace had a daily capacity of ten tons and was a hot blast charcoal furnace. After being operated six months this furnace was found to be unsatisfactory, abandoned, torn down and a furnace with a capacity of fifty tons daily was constructed in its stead. On account of the very refractory nature of the ore being used this new furnace did not meet expectations, and after being operated for several months was reconstructed and then operated very successfully, as far as the grade of pig iron produced was concerned, about six months each year until 1891, when the furnace was closed down permanently.

The Irondale plant was first built for the purpose of using a deposit of limonite or bog ore which occurred south of there in the Chimacum valley, but the iron produced was found to be of a rather poor quality and the deposit proved to be very limited in quantity, so a magnetite found on Texada island, a British island situated in the Straits of Georgia, about one hundred and twenty-five miles northwest of Port Townsend, was mixed with the bog ore. It was found that a mixture of these two ores produced a very high grade of pig iron, but owing to the fact that there was an import duty of seventy-five cents a ton on the Texada ore, and charcoal being expensive, on account of having nothing but soft wood from which to make it, coke twelve dollars a ton, labor high, and the price of iron low, it was found to be a losing proposition, and it is claimed that every day the furnace was operated it was at a loss, and hence in 1891 it was closed down and had been allowed to go to decay until March, 1901, when Pennsylvania capital became interested in the matter and what is known as the Pacific Steel Company was formed and obtained control of the old Irondale plant for a consideration of \$45,000. This new company immediately began the work of putting the plant in first class condition again and have

expended about \$100,000 on the property. December 15, 1901, the plant was again put in operation.

The new plant has a stack 60 feet high, 12 feet in the bosh, 6 feet on the crucible, and a capacity of about 50 tons a day. The power to drive the machinery for hoisting and crushing the ore will be furnished by a battery of four steam boilers, while large blowing engines will furnish the blast for the furnace.

At the present time ores from Texada island and from Hamilton, Skagit county, are being used. These two grades of ore are mixed in the proportion of 700 tons of Texada ore to 50 tons of Hamilton ore or about 93 per cent. Texada and 7 per cent. Hamilton. The principal flux used is limestone from the Roche Harbor lime works. The following analysis shows the composition of this limestone: Calcium carbonate, 98.32 per cent.; iron and alumina, 1.13 per cent.; silica, .44 per cent.; phosphorous, .11 per cent. In addition to the limestone a small amount of sand is used.

A little coke from Cokedale has been used, but the principal fuel is charcoal, and this is produced by the company's own charcoal plant on the premises. There are, for the burning of this charcoal, twenty kilns each 30 feet high and 30 feet in diameter at the base and holding 75 cords of wood each.

These twenty kilns will burn 180 cords of wood a day and have a total capacity of 180,000 bushels of charcoal per month. A sawmill and splitting-machine have been installed, so that the company now buys the logs and makes its own cordwood at the works. Machinery is being installed also for conveying automatically the wood to the kilns.

The ores from Texada island and from Hamilton are loaded on scows, transported to the plant and dumped into the bunkers. From the bunkers the Texada ore is hauled in small cars into the yard, where it is arranged in large heaps and roasted to get rid of sulphur and also to make it more easy to reduce in the furnace. Castings are made three times a day; that is, every eight hours. The pig iron at present is sold to the various foundries around Puget sound, Oregon and British Columbia. The company, however, expects in the near future to ship to San Francisco.

The old plant when in full operation employed altogether, in the mines, cutting wood and burning charcoal, and at the fur-

nace, about 250 men. The new plant will employ directly and indirectly about 300 men.

There are a number of places in the state where considerable development work has been done, but the bog ores at Irondale are the only ones from which iron has been produced. From 1889 to 1892, inclusive, development work was quite vigorously pushed in the Clealum district in Kittitas county by a Scotch company who were contemplating the building of an extensive plant at Kirkland, on the shore of Lake Washington, but for some unknown reason work was stopped in 1892, and nothing has been done since.

In 1881 Mr. F. M. Guye discovered and located iron mines in the Cascade mountains, one and one-half miles northwest of Snoqualmie pass on the south fork of the Snoqualmie river. Soon after this he also found another deposit about six miles northeast of North Bend, the present terminus of the Snoqualmie branch of the Seattle & International Railroad.

Other properties have been located in the Snoqualmie pass district and some development work done, but at the present time (1901) nothing is being done toward developing any of these properties.

About 1881 iron ore was discovered by Mr. J. J. Conner, in Skagit county, near Hamilton on the Skagit river. Since that time these same deposits have been traced, and locations made, for several miles along the south bank of the Skagit river above Hamilton, and the ores occurring near Marble Mount are probably a continuation of these same Hamilton ores. Considerable development work has been done on some of the properties in this district, but no very great depth has been reached.

In 1881 two tons of the iron ore from the Hamilton district were sent to Tacoma and tests were made at the smelter there, and a company formed to build a plant at that place. In 1887 twenty tons were tested at Irondale. This ore was sent by J. J. Conner, of Hamilton.

About eleven miles northwest of Hoodsport in Mason county, a number of iron mines have been located and some development work done.

In Stevens county iron ores occur near Colville and Valley, each of which is on the Spokane Falls & Northern Railroad. At one time the deposits near Valley were being worked and the ore

shipped to Tacoma to be used as a flux in the smelter located there.

THE DISTRIBUTION OF IRON ORES IN WASHINGTON.

Iron ore occurs in many places in the state of Washington, but only in a few places is there any prospect of the known deposits ever being utilized for the manufacture of iron. There may, however, be many mines located in the future that we know nothing about at present, as there is a large part of the state that has not been very thoroughly prospected as yet, and for that reason we do not know what we may have in the way of iron ore.

The principal known deposits are in the following counties; Skagit, King, Kittitas, Stevens, and Mason.

Bog ores are found in a number of places in the following counties; Whatcom, Clallam, Spokane, Whitman, Thurston, and Jefferson.

ANALYSES OF WASHINGTON IRON ORES.

The Iron Ores of Washington.

9

No.	Locality.	Analyzed by.		1.05	.....
		Calcium (CaCO ₃)....	Manganese (Mn ₂ O ₃)....		
1..	Olympic Mountains, Mason county—				
1..	Ore from cabins.....	16.34	0.13	27.14	11.28
2..	Pomeroy mine	19.25	Trace.	.65	1.13
3..	Pomeroy mine	4.13	0.21	19.04	6.00
4..	Pomeroy mine, 4,000 feet above river.....	10.66	0.16	27.39	49.16
5..	Hoodsport mine.....	10.20	0.16	11.64	1.58
6..	Hoodsport mine.....	13.76	0.20	29.35	70.34
	British Columbia—				
7..	Texada island.....	67.91	2.96	.....	.....
8..	Black Hills, Chehalis county—				
8..	Float	52.31	..	13.04	1.4
9..	Float	48.18	..	25.02	23
10..	Black sand	43.72	..	24.14	18
	Hamilton District, Skagit county—				
11..	From tunnel on Inaugural.....	43.89	19.98	.....	3.98
12..	Hamilton mine.....	32.14	30.53	.....	5.82
13..	Hamilton mine, near middle of vein.....	36.72	20.24	.....	9.77
14..	Inaugural mine, surface.....	31.08	31.82	.....	11.74
15..	Inaugural, near wall.....	33.88	32.94	.....	13.04
16..	Inaugural	43.91	18.36	.....	5.83
17..	Treadwell mine	43.72	22.85	.....	7.31
18..	Treadwell mine	32.92	28.05	.....	8.81
19..	Pittsburg, upper ledge.....	29.11	32.46	.....	8.92
20..	Inaugural, from dump.....	39.44	20.84	.....	3.09
21..	New opening	49.60	59	.....	3.08
22..	Vein No. 5	42.43	24.13	.....	3.78
	Snoqualmie Pass, King county—				
20..	Guye mine.....	67.13	3.60	None	8.11
21..	Guye mine.....	66.82	4.20	.....	6.71
25..	Denny mine	62.45	5.78	.....	8.63
36..	Denny mine	68.54	1.89	.....	3.95

ANALYSES OF WASHINGTON IRON ORES—CONCLUDED.

No.	LOCALITY.	Analyzed by .						
		Calcium (CaCO ₃) ...	Manganese (Mn ₂ O ₃) ...	Alumina (Al ₂ O ₃)	Insoluble residue.....	Sulphur.....	Phosphorus (P)	Silica (SiO ₂) .
22..	Clealum District, Kittitas county—							
Emerson mine		47.10	15.58	None	None	1.92	6.02	Not det... ..
Hard Scrabble mine		47.87	14.00	"	"	26.96	12.22	"
Pebby ore		46.24	7.50	Trace	"	5.67	8.29	"
Laminated ore from near Camp creek		47.10	8.70	"	"	14.23	4.80	"
Laminated ore from near Cabin		51.68	7.84	"	"	14.23	4.80	"
Massive ore from near cabin		54.40	5.54	"	"	14.23	4.80	"
Massive ore from Camp creek		51.13	6.94	"	"	14.23	4.80	"
Best laminated ore from Camp creek		57.12	5.68	"	"	14.23	4.80	"
Colville and Valley Districts, Stevens county—								
Silver King mine		67.56	1.66	" .....	.38	None	"	"
Silver King mine		68.10	1.12	" .....	.25	"	"	"
I. X. L. mine		56.58	4.49	.31 .....	.32	2.00	2.48	"
I. X. L. mine		50.48	14.90	.30 .....	.32	1.85	1.85	"
Capital mine		59.19	5.80	.16 .....	.33	3.18	3.18	"
Vigilant mine		58.33	3.54	.22 .....	.21	17.23	17.23	"
Mineral point		50.05	10.12	.20 .....	.42			
Irondale District, Jefferson county—								
Bog ore		53.67	1.09	{ Not det.	9.67 .....	.20 .....	.95	Fulmer.
Bog ore with gravel		28.48 .....	.17	{ "	40.35 .....	.92	2.10	"
Cheney District, Spokane county—								
Bog ore		35.12	16.30 .....	.31 .....	.19	10.94	Not det...	Shedd.

THE CHARACTER AND COMMERCIAL VALUE OF THE IRON ORES OF WASHINGTON.**VARIETIES OF ORES.**

The iron ores of Washington are magnetites, hematites, limonites, or hydrous sesquioxide of iron, known commercially as brown hematite, and mixtures of hematite and magnetite. The Snoqualmie pass ores are the only true magnetites while the Clealum, Hamilton and a part of the Stevens county ores are mixtures of magnetite and hematite. The Jefferson county ores, and part of the Stevens county ores, are limonites or bog ores. In several other places in the state the bog ores have been found in small quantities but they are of no commercial importance. The iron ore in Mason county is quite largely a hematite but most of it is of very little commercial value. In the Clealum district there is some quite strong lodestone ore.

COMMERCIAL VALUES.

One of the most important questions in connection with the commercial value of an iron ore is whether or not it is suited for the manufacture of Bessemer steel. This point is determined quite largely by the amount of phosphorus the ore contains, and the extreme limit has been placed at .05 per cent. for an ore that contains 50 per cent. of iron. While it is true that perhaps the question of the amount of phosphorus is one of the most important ones, it is necessary, of course, that the ore should have iron enough to make it profitable to work it and that the amount of silica, sulphur, and other impurities must be small enough so as not to injure it. The amount, however, of sulphur or silica allowable in a Bessemer ore is considerable more than that of phosphorus. It will be found by examination of the table, given on a following page, of analyses of ores from some of the different mines in the United States and Cuba that most of the ores are non-Bessemer ores. These ores, however, are used for making the commoner grades of iron but would not bring so high a price in the market as the Bessemer ores.

The accompanying table of analyses of Washington iron ores shows that they range in phosphorus from nothing to 1.09 per cent. As far as the per cent. of phosphorus is concerned a few of them, as far as other impurities also are concerned, would

be classed as Bessemer ores, but the larger part would be non-Bessemer. In some cases where the silica is within the Bessemer limit there is quite a large amount of alumina and that in connection with the silica would probably exclude those ores from the Bessemer class. Some of the ores contain a high per cent. of manganese and quite a number of them have from 7 per cent. to 14.28 per cent., while in one instance as high as 42.58 per cent. was obtained so that some of these might be valuable for the manganese they contain, provided they occur in anything like large bodies.

As regards their per cent. of iron the Washington ores range from 28.48 to 68.54 per cent. In taking the samples for analyses the intention was to get average samples, but as on all the properties, with one or two exceptions, very little work has been done, it was a difficult matter to sample systematically and I presume the analyses show the per cent. of iron to be a little above the average of the whole deposits. The analyses show that with the exception of a few samples from one particular locality, and which were known to be of no value as iron ores before the analyses were made, that very few of the ores have less than 35 per cent. of iron and quite a good many of them have from 40 to 60 per cent.

In their contents of silica the Washington ores have as wide a range as they have in their contents of iron. The table of analyses shows the silica to range from a little less than 2 to a little less than 33 per cent. The amount of silica allowable in an iron ore is determined somewhat, of course, by the amount of iron the ore contains but in a general way 15 per cent. is given as about the limit. The analyses show that quite a good many of the Washington ores contain less than 15 per cent. of silica while there are a number of them that contain more than 15 per cent. of silica. A mixture of these two grades might be made in such proportions as to keep the silica below the limit and in this way considerable at least of the ore high in silica might be used.

In their contents of sulphur the Washington ores range from nothing to .42 per cent., which is really quite low and in fact much lower than that of many other ores that find a ready market.

As shown by the analyses a number of the Washington ores contain a large per cent. of alumina ranging from practically none to as high as 14.23 per cent. This large amount of

alumina in an iron ore is very uncommon and so much of it would be injurious to the ore.

SUMMARY.

The above facts show the iron ores of Washington, as far as their commercial value is concerned, to be principally non-Bessemer, but a few of them are Bessemer in quality. In iron they vary from 28.48 to 68.54 per cent.; in silica they vary from 2 to 33 per cent.; in alumina some of them run as high as 14.23 per cent.; in sulphur they are usually low; a few of them contain considerable manganese. The alumina and silica would have about the same effect or require about the same treatment, and taking the two together in some of the ores the per cent. would be very high.

The following table, taken from Vol. I of the Annual Report of the Arkansas Geological Survey for 1892, p. 15, comprising a number of analyses of iron ores from well known mines in the United States and Cuba, is given for comparison with the analyses of Washington ores:

ANALYSES OF IRON ORES OF VARIOUS MINES IN THE UNITED STATES AND CUBA.

No.	Locality.	Kind of ore.	Analyzed by —		
			Sulphur.....	Phosphorus..	Iron
1.	Tilly Foster mine, Putnam county, N. Y.	Magneticite.....	48.91	12.18	0.016
2.	Crown Point, Essex county, N. Y.	Magneticite.....	63.80	0.030	0.548
3.	Crown Point, Essex county, N. Y.	Magneticite.....	52.25	0.107	Richmond.
4.	Moriah (Post Henry) N. Y.	Magneticite.....	62.64	0.908	Richmond.
5.	Chateaugay mine, Clinton county, N. Y.	Magneticite.....	66.00	0.003	Richmond.
6.	Chateaugay mine, Clinton county, N. Y.	Magneticite.....	52.47	18.44	Richmond.
7.	Andover mine, Susser county, N. J.	Magneticite.....	36.91	21.86	Blair.
8.	Andover mine, Sussex county, N. J.	Magneticite.....	62.31	0.022	Blair.
9.	Hackelbarney mine, Morris county, N. J.	Magneticite.....	48.38	0.001	0.059
10.	Cornwall mine, Lebanon county, Pa.	Magneticite.....	64.90	3.98	Chauvenet.
11.	Cornwall mine, Lebanon county, Pa.	Magneticite.....	57.05	8.65	McCread.
12.	Cornwall mine, Lebanon county, Pa.	Magneticite.....	51.45	12.27	McCreat.
13.	French creek, Chester county, Pa.	Magneticite.....	56.13	0.040	McCreat.
14.	Hecla furnace, Lawrence county, Ohio	Siderite.....	33.29	0.144	Whitfield.
15.	Monroe furnace, Jackson county, Ohio	Limonite.....	49.32	0.145	King.
16.	Dover & Co., Amhurst county, Va.	Specular and magnetite.....	48.47	21.58	King.
17.	Panic furnace, Smyth county, Va.	Limonite.....	46.61	11.47	Gorch.
18.	Cranberry, Mitchell county, N. C.	Magnetite.....	32.37	29.99	Pitman.
19.	Cranberry, Mitchell county, N. C.	Magnetite.....	44.08	0.007	Pitman.
20.	Penn. furnace, Greenup county, Ky.	Limonite.....	54.39	0.167	Pitman.
21.	Shepherd bank, Lawrence county, Ky.	Carbonate.....	40.61	14.37	King.
22.	Taylor bank, Carter county, Tenn.	Limonite.....	49.73	13.68	King.
23.	Eureka mine, Jefferson county, Ala.	Fossil ore.....	51.25	16.39	King.
24.	Eureka mine, Tuscaloosa county, Ala.	Limonite.....	46.59	15.07	White.
25.	Shelby mine, Shelby county, Ala.	Limonite.....	52.82	6.62	White.
26.	Pilot Knob, Iron county, Mo.	Specular ore.....	59.52	12.17	White.
27.	Iron mountain, St. Francois county, Mo.	Specular ore.....	64.67	0.019	King.
28.	Iron mountain, St. Francois county, Mo.	Specular ore.....	59.96	0.398	King.
29.	Republic mine, Marquette county, Mich.	Specular ore.....	67.02	3.38	Gooch.
30.	Norway mine, Menominee county, Mich.	Specular ore.....	60.20	12.43	Pitman.
31.	Commonwealth mine, Marquette county, Wis.	Specular ore.....	59.36	0.224	Gooch.
32.	Black River Falls, Jackson county, Wis.	Specular ore.....	37.09	0.047	King.
33.	Iron mountain, Dodge county, Wis.	Fossil ore.....	56.52	0.534	King.
34.	Nipigon, Minn.	Red specular ore	63.88	12.97	Trace.
35.	Vermilion range, Minn.	Red specular ore	67.17	4.61	0.083
					0.020

ANALYSES OF IRON ORES OF VARIOUS MINES IN THE UNITED STATES AND CUBA—CONCLUDED.

No.....	LOCALITY.	Kind of ore.	Analyzed by—		
			Sulphur.....	Phosphorus..	Iron.....
36..	Marion county, Texas.....	Limonite.....	47.55	8.92	0.139
37..	Cherokee county, Texas.....	Limonite.....	42.25	25.13	0.113
38..	Llano county, Texas.....	Magnetite.....	63.74	10.08	0.018
39..	Breece mine, Lake county, Col.....	Specular hematite.....	61.51	.....	0.038
40..	Juragua, Cuba.....	Specular hematite.....	61.94	7.18	0.027
41..	Juragua, Cuba.....	Magnetite.....	62.64	.....	0.028
42..	Signa, Cuba.....	Magnetite.....	58.10	15.50	0.034
					0.046

THE IRON MINING POSSIBILITIES OF WASHINGTON.

Conditions Necessary for Profitable Iron Mining.

As already stated, the value of an iron ore deposit depends not alone upon the quantity and quality of the ore, but also upon its position as regards fuel, fluxes, transportation and markets, as well as facilities for mining.

Conditions in Skagit County.

In Skagit county along the south bank of the Skagit river, from Hamilton to Marble Mount, occur deposits of iron ore which are very favorably situated as far as fuel, fluxes and transportation are concerned. The Seattle & Northern Railroad is built as far as Hamilton and could easily be extended if it were necessary.

There are five different veins or ore bodies in this district, ranging in thickness from 6 to 50 feet, and dipping to the south and a little to the west at an angle of 55 degrees.

The conditions for mining in this district are very favorable, as a large body of the ore occurs high up the mountain some distance above the river, so that a tunnel could be put in from down near the river and a large body of the ore mined at a minimum expense.

Just above the iron ore occurs coal which is said to be of coking quality and in large quantities, but at present (1901) nothing is being done to develop these deposits. About 12 miles west of Hamilton, at Cokedale, deposits of good coking coal occur and the coke from here could be used in connection with the Hamilton ores should it be found on further investigation that the Hamilton coals are not coking coals.

Limestone suitable for fluxes are found in close proximity to the iron ores of this locality, and a few miles east of Hamilton large quantities of limestone occur.

Conditions in Kittitas County.

The iron deposits of Kittitas county are situated about twenty miles north and a little west of Clealum on the Clealum river, a tributary of the Yakima river, in the eastern spurs of the Cascade range. This district is reached by wagon road from Roslyn, the present terminus of a short branch of the Northern Pacific Railroad, up the valley and canyon of the Clealum river.

As given by the U. S. Geological Survey, Roslyn has an elevation of 2,273 feet above sea level, and the Clealum valley, where the iron ores occur, has an elevation of 2,800 to 3,000 feet above sea level. For about 17 miles of this distance from Roslyn, or to the Salmon Lasac river, the valley has an average grade of about 20 feet to the mile, but for the rest of the distance above there, to where the iron occurs, the grade is much steeper and the canyon narrower. On the west side of the valley, opposite the iron-ore deposits, the mountains rise very abruptly to an altitude of about 6,670 feet above the sea, or 3,670 to 3,870 feet above the valley; on the east the slope is much more gradual.

Conditions in King County.

In King county magnetite occurs in the Cascade mountains at a distance of about two and one-half or three miles north and a little west of Snoqualmie pass. These ores are about twenty-eight miles from North Bend, and about fourteen miles from Martin, a station on the main line of the Northern Pacific Railroad, on the east side of the summit of the Cascade mountains. The state wagon road from North Bend through Snoqualmie pass passes within about two and one-half miles of these deposits, and the Seattle & International Railroad has been located through this pass, but at present is built only as far as North Bend.

The ore in this district is not difficult of access, but it would have to be shipped by rail to some point where fuel is convenient, as there is no coal in that locality.

Conditions in Stevens County.

In Stevens county iron-ore deposits occur in two or three localities, which have been worked and the ore shipped to the Tacoma smelter and used as a flux, but they have not been used for the production of iron.

Twenty miles north and a little east of Colville, on the head waters of Clugston creek are a number of mines which have been located as iron properties, and considerable work has been done in developing one of these locations, and a wagon road has been built to the property.

Eleven miles west and a little south of Valley, a station on the Spokane Falls & Northern Railway, is situated another body of iron ore and some mining has been done here. This district is

reached by a trail, which leaves the United States Marble Company's wagon road about two miles from their quarry.

About two miles east of Valley are some more iron deposits, and these are very easy of access. These deposits were worked for several years on a small scale and the ore was brought by teams to Valley and shipped to Tacoma and used as a flux, but at present nothing is being done with these deposits.

The iron ores of Stevens county are all easy of access and the localities in which the iron occurs are well supplied with material for fluxes but lack fuel, hence the ore would probably have to be transported to some other locality in order to utilize it.

Conditions in Mason County.

About eleven miles northwest of Hoodsport, in Mason county, are deposits on which a number of locations have been made for iron. Hoodsport is a small town situated near the southern end of Hood's canal, and from this point to the iron deposits there is a good wagon road and a railway could easily be built if there was a demand for it. These deposits are about four miles above the upper end of Lake Cushman, on Boulder creek, about two hundred yards above where it empties into the Skokomish river. The country around Lake Cushman is very rough and mountainous. The mountain in which the iron ore occurs reaches an altitude of about five thousand feet above sea level and is quite steep. The ore in this district, if ever used, would have to be shipped to some other locality, as there is neither fuel nor fluxes to be found in connection with these deposits.

LAKE CUSHMAN DISTRICT.

ANALYSES OF IRON ORES FROM LAKE CUSHMAN, MASON COUNTY.

No.	Mine.	Iron.	Insoluble residue.....	Phosphoric acid (P_2O_5)	Alumina (Al_2O_3)	Manganese (Mn_3O_4)	Calcium ($CaCO_3$)	Analyst
1..		16.34	24.20	.13	8.00	27.14	11.28	Fulmer.
2..		19.25	70.50	Trace	.65	.32	1.13	"
3..		4.13	19.04	.21	6.91	42.58	6.00	"
4..		10.66	27.39	.16	2.33	5.18	49.16	"
5..		10.20	11.64	.16	1.24	1.58	70.34	"
6..		13.76	29.35	.20	.....	4.18	36.91	"

The above analyses were made from what are thought to be fair samples of the deposits being prospected in this locality for

iron. The analyses show that so far as iron is concerned the deposits have no value whatever. Number one and number three have considerable manganese and if they should be found in large quantities might be valuable on that account.

BLACK HILLS.

ANALYSES OF IRON ORES FROM THE BLACK HILLS, CHEHALIS COUNTY.

No.	Mine.	Iron.	Alumina (Al ₂ O ₃).....	Manganese (Mn ₃ O ₄).....	Analyst
8.	Float.....	52.31	13.04	1.06	.14
9.	"	48.18	25.02	.02	.23
10.	Black sand	43.72	24.14	11.65	.18

The above analyses are from samples of float found in the Black hills and no ledges have been found as yet. Number eight has a fair per cent. of iron, but it also carries considerable titanium, and this would tend to injure it for the manufacture of iron. The samples were given me by parties in Olympia, and I know nothing about the conditions under which they were found. Numbers eight and nine looked as if they were nodules of consolidated black sand.

HAMILTON DISTRICT.

ANALYSES OF IRON ORES FROM THE HAMILTON DISTRICT, SKAGIT COUNTY.

No.	Mine.	Silica (SiO ₂) ..	Iron (Fe ₂ O ₃) ..	Alumina (Al ₂ O ₃) ..	Phosphorus (P ₂ O ₅) ..	Sulphur	Iron	Manganese (Mn ₃ O ₄) ..	Calcium (CaCO ₃) ..	Analyst.
11..	Inaugural	19.98	62.70	3.30	.25	.....	43.89	12.30	3.98	Thatcher.
12..	Hamilton	30.53	45.92	7.25	.72	.06	32.14	11.74	5.82	"
13..	Hamilton	20.24	52.46	7.40	Trace .....	.....	36.72	13.04	9.77	"
14..	Inaugural	31.82	44.40	6.79	.41	Trace	31.08	14.28	5.83	"
15..	Hamilton	32.94	48.40	2.57	2.43	.16	33.88	7.31	8.81	"
16..	Inaugural	18.36	62.73	3.09	1.58	.....	43.91	12.00	8.92	"
17..	Treadwell	22.85	62.46	3.17	1.00	.....	43.72	8.08	3.78	"
18..	Pittsburg	28.05	47.03	8.43	.70	.....	32.92	8.11	8.06	"
19..	Pittsburg	32.46	41.59	8.56	.45	.....	29.11	13.11	6.71	"

THE LOCATION AND MODE OF OCCURRENCE OF THE ORE.

The iron ore deposits in the Hamilton district occur on the south side of the Skagit river at Hamilton, in the western spurs

of the Cascade range, about twenty-five miles above the mouth of the river. Deposits have been found as far up the river as Marble Mount, which is about twenty-five miles above Hamilton. The Hamilton deposits may be reached by the Seattle & Northern Railroad and are about fifty miles, by rail, from the tide water at Anacortes, or about twenty-five by boat by the way of the Skagit river. At Hamilton, where the iron deposits occur, the valley has an altitude, as given by the U. S. Geological Survey, of 94.56 feet above sea level, and at Marblemount, the point farthest up the river where the iron is known to occur, an elevation of 312.96 feet, making a grade for the valley from Hamilton to Marblemount of nine feet to the mile.

At Hamilton, the mountains on the south side of the valley rise abruptly from the river to an altitude above sea level of about 3,000 feet, while on the north side of the valley the ascent is more gradual. The country rock through this locality is sandstone, limestone, shales and slates. The iron ore occurs in the slates and lies parallel with the bedding.

Occurring in connection with the iron in this district, especially across the river from Hamilton, and lying above it are at least four seams of what is said to be a good grade of coal. Some work has been done on this coal, but for some reason it has been stopped and at present nothing is being done. The first vein is from 1,000 to 1,200 feet above the iron ore, and has a thickness of from 8 to 10 feet of coal with three streaks of boney matter from $1\frac{1}{2}$ to 4 inches in thickness. Just below the coal is about 300 feet of sandstone, and then comes the slates in which the iron occurs. The second vein occurs about 100 feet above the first and has 6 feet of coal comparatively free from dirt. The formation between the two seams of coal is a gray sandstone with 4 feet of fire clay just below the upper vein of coal. From the second vein of coal to the third is 1,100 feet of gray sandstone. Number 3 is 3 feet thick and contains no dirt. Vein number 4 is 1,200 feet above 3, and the formation between the two is sandstone.

EXTENT OF IRON DEPOSITS.

Outcrops of iron-ore appear at intervals along the valley from Hamilton to Marblemount, a distance of about twenty-five miles. While the deposits have been found in a number of places along



IRON MOUNTAIN, NEAR HAMILTON.



INAUGURAL IRON MINE, NEAR HAMILTON.

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the trend there has not been work enough done to tell definitely just what the relations of the different outcrops are to each other, but I am inclined to think they are lenses rather than veins and probably not continuous between the outcrops. The ore bodies vary in thickness from a few feet to 30 feet. From Hamilton to Birdsview, a distance of six miles, the iron ores appear at intervals on the south side of the Skagit river in five lines, one above the other, while at Marblemount only two lines of outcrops have been found so far. These outcrops trend approximately east and west and have a dip to the southwest of about 55 degrees.

CHARACTER AND COMPOSITION OF THE HAMILTON ORES.

The Hamilton ores are dark colored, massive appearing ores, having a medium specific gravity, for an iron ore, and when powdered some of them have somewhat of a reddish appearance, while others have a very dark, almost black appearance. The ores are all more or less magnetic. The reddish cast to the powder, however, shows that they contain some hematite. In places, as for instance in the tunnel on the Inaugural claim, the iron is found to be intimately mixed with a very white granular quartz, but most of the ore in the district seems to be free from this.

The following analysis, by R. W. Thatcher, shows the composition of the iron ore from the tunnel on the Inaugural mine, Hamilton district, Skagit county :

	Per cent.
Iron.....	43.89
Silica.....	19.98
Phosphorus.....	.11
Sulphur.....	.....
Alumina (Al_2O_3).....	3.30
Manganese (Mn_3O_4).....	12.30
Calcium (CaCO_3)	3.98

A tunnel has been driven into the side of the mountain a distance of approximately 50 feet, to tap the iron ore on the Inaugural mine, and the sample from which the above analysis was made was taken from the face of that tunnel. In this tunnel, in places, the iron is intimately mixed with a very fine, white, granular quartz, such as was not found in any other place. The analysis shows the ore to be a little low in iron, somewhat high in silica, and quite a good per cent. of manganese, in fact enough to make a fair grade of spiegeleisen.

The following analysis, by R. W. Thatcher, shows the composition of the ore from the Hamilton mine :

	<i>Per cent.</i>
Iron	32.14
Silica.....	30.53
Phosphorus.....	.72
Sulphur.....	.06
Alumina (Al_2O_3).....	7.25
Manganese (Mn_3O_4).....	11.74
Calcium (CaCO_3).....	5.82

This is an average sample from this mine and is thought to show fairly well the character of the ore taken as a whole. The analysis shows the ore to be low in iron, very high in silica and phosphorus, with some alumina and quite a high per cent. of manganese. The ore, however, taken by itself, would not be a very valuable one from which to manufacture iron.

The following analysis, by R. W. Thatcher, shows the composition of the ore from the Hamilton mine, near the middle of the vein :

	<i>Per cent.</i>
Iron	36.72
Silica.....	20.24
Phosphorus.....	Trace
Sulphur.....	.....
Alumina (Al_2O_3).....	7.40
Manganese (Mn_3O_4).....	13.04
Calcium (CaCO_3).....	9.77

The ore in the Hamilton mine is of two grades, that in the central part of the ore body being a little better ore than that near the outer part. In the particular places where the openings have been made, there is about 18 inches of this better grade of ore. The above analysis shows the ore to be low in iron, high in silica and manganese, with considerable alumina and calcium. The amount of manganese in this ore would, perhaps, make it of value for producing spiegeleisen.

The following analysis, by R. W. Thatcher, shows the composition of the ore from the surface of the Inaugural mine. :

	<i>Per cent.</i>
Iron	31.08
Silica	31.82
Phosphorus.....	.18
Sulphur.....	.....
Alumina (Al_2O_3).....	6.79
Manganese (Mn_3O_4).....	14.28
Calcium (CaCO_3).....	5.82

The ore from which the above analysis was made came from the surface and shows the fact that the ore, in this particular deposit at least, has increased in iron with depth while it has de-

creased in silica, alumina, manganese, calcium and phosphorus. This sample is low in iron, high in silica, manganese and phosphorus. The per cent. of manganese is high enough to make a fair grade of spiegeleisen.

The following analysis by R. W. Thatcher shows the composition of the ore from near the wall of the Hamilton mine:

	Per cent.
Iron	33.88
Silica	32.94
Phosphorus.....	1.06
Sulphur .....	.16
Alumina (Al_2O_3)	2.57
Manganese (Mn_3O_4)	7.31
Calcium (CaCO_3)	8.81

The sample from which the above analysis was made is the poorer grade of ore from the Hamilton mine and, as the analysis shows, it contains less iron, manganese, alumina and calcium and more silica, phosphorus and sulphur. The per cents. of phosphorus, sulphur and silica are so high that they preclude its being classed as a Bessemer ore. It might, however, be used in connection with a better grade of iron ore, such as the Snoqualmie pass ore, and make a good pig iron.

The following analysis by R. W. Thatcher shows the composition of the ore from the shaft of the Inaugural mine:

	Per cent.
Iron	43.91
Silica.....	18.36
Phosphorus.....	.69
Sulphur .....	....
Alumina (Al_2O_3)	3.09
Manganese (Mn_3O_4)	12.00
Calcium (CaCO_3)	8.92

The sample from which the above analysis was made was taken from a shaft that has been sunk to the depth of 85 feet on this property, and shows the character of the ore at that depth. The ore is not very high in iron but contains a high per cent. of silica, phosphorus, and manganese. In some cases, however, ores having a lower per cent., even, of iron than this one has are used.

The following analysis by R. W. Thatcher shows the composition of the ore from the Treadwell mine.

	Per cent.
Iron	43.72
Silica.....	22.85
Phosphorus.....	.44
Sulphur .....	....
Alumina (Al_2O_3)	3.17
Manganese (Mn_3O_4)	8.08
Calcium (CaCO_3)	3.78

The Treadwell mine is located near Marblemount, which is twenty-five miles above Hamilton on the Skagit river, and the ore is about the same grade as that at Hamilton. This particular sample shows the per cent. of iron to be a little low, with a high per cent of silica, phosphorus and manganese.

The following analysis by R. W. Thatcher shows the composition of the ore from the Pittsburg mine.

	<i>Per cent.</i>
Iron	32.92
Silica.....	28.05
Phosphorus.....	.31
Sulphur.....	.....
Alumina (Al_2O_3)	8.43
Manganese (Mn_3O_4)	8.11
Calcium (CaCO_3)	8.06

The sample from which the above analysis was made came from the ore body which is situated lowest down on the hill and shows the ore to be of a very poor quality, being low in iron, high in silica and phosphorus.

The following analysis by R. W. Thatcher shows the composition of the ore from the Pittsburg mine.

	<i>Per cent.</i>
Iron	29.11
Silica.....	32.46
Phosphorus.....	.20
Sulphur .....	.....
Alumina (Al_2O_3)	8.56
Manganese (Mn_3O_4)	13.11
Calcium (CaCO_3)	6.71

There are two ledges or ore bodies on the Pittsburg mine and the sample from which the above analysis was made came from the upper one of the two. The analysis shows the ore to be low in iron and high in silica, phosphorus, alumina, and manganese. The only redeeming feature this ore has is its high per cent. of manganese and with the very high per cent. of silica it has, it is very doubtful if it will prove of very much value to use by itself, but might be used in connection with some good high grade ore, like the Snoqualmie pass ore.

The following analysis by E. Fulmer shows the composition of the ore from a new location by J. J. Conner.

	<i>Per cent.</i>
Iron	46.60
Insoluble residue.....	27.04
Phosphorus.....	.59
Sulphur.....	Not Det
Alumina (Al_2O_3)	None
Manganese (Mn_3O_4) .....	.19
Calcium (CaCO_3)	8.95

The above analysis shows the sample to have been above the average in iron and to be very similar to the ores of this district in other respects.

The following analysis by S. Shedd shows the composition of the ore from the upper deposits or the one just below the coal:

	Per cent.
Iron.....	42.43
Silica.....	24.13
Phosphorus.....	.64
Sulphur.....	.25
Alumina (Al_2O_3).....	9.54
Manganese (Mn_3O_4).....	Not det.
Calcium (Ca CO_3).....	" "

The sample from which the above analysis was made was taken from the vein highest up above the river, and while no work has been done here the analysis shows the ore to be a little above the average in the amount of iron it contains, of the ores in the Hamilton district, and in other respects to be about the same as the average ore of this locality.

SNOQUALMIE PASS DISTRICT.

ANALYSES OF IRON ORES FROM SNOQUALMIE PASS, KING COUNTY.

No.	Mine.	Silica.....	Iron oxide.....	Aluminum oxide.....	Phosphoric acid.....	Sulphur.....	Iron.....	Phosphorus.....	Analyst.
20.	Guye.....	8.60	95.45	.....	Trace.....	.....	66.81	Trace.....	Fulmer.
21.	Guye.....	4.20	95.45	.....	.....	.....	66.82	.....	Fulmer.
35.	Denny.....	5.78	89.22	5.34	.....	21	62.45	.....	Shedd.
36.	Denny	1.89	97.92	.28	.....	.25	68.54	.....	Shedd.

THE MODE OF OCCURRENCE OF THE SNOQUALMIE PASS ORES.

The iron ores of the Snoqualmie Pass district occur on the south fork of the Snoqualmie river near the summit of the Cascade mountains.

The pass, as determined by the United States Geological Survey, has an altitude above sea level of 3,131 feet, and Guye's peak 6,980 feet and Denny mountain 5,766 feet. The ores occur in Guye's peak and Denny mountain at an altitude of from 1,500 to 2,000 feet above the Snoqualmie river. The ore appears to occur in beds or isolated masses and not in veins. The country rock in this locality is marble, limestone, granite, and conglomerate and the iron ore occurs in connection with the limestone and marble more frequently than with the other kinds of rock. In

the tunnel on the Denny mine is found a coarse-grained white marble in which the particles are very loosely cemented together.

CHARACTER AND COMPOSITION OF THE SNOQUALMIE PASS ORES.

The iron ores of the Snoqualmie pass district are dark-colored heavy ores and vary from quite porous to very fine-grained masses. They have somewhat of a metallic luster, are strongly magnetic and when powdered give a black streak.

Below are given descriptions of the individual properties in Snoqualmie pass district.

THE F. M. GUYE PROPERTIES.—These properties are located on what is known as Guye's peak, about four miles northwest from Snoqualmie pass. Considerable development work has been done on these properties and some fine magnetic iron has been found here, but the question that has not been definitely settled as yet is the question of quantity. The ore here occurs in connection with marble and limestone principally.

The following analyses by Professor Elton Fulmer shows the composition of the ore from these properties:

	No. 1.	No. 2.
Iron.....	66.81	66.82
Silica.....	3.60	4.20
Phosphorus.....	.....	Trace.
Sulphur.....	.....	.....

The analyses are of samples collected from two different localities and show the ore to be a very high grade ore almost free from phosphorus and sulphur, and as already stated, the only question that remains in connection with these deposits is the one of quantity.

THE DENNY PROPERTIES.—The Denny properties are located on what is known as Denny mountain, a high prominent peak about three and one-half miles south of Guye's peak, and about four miles southwest of Snoqualmie pass. A tunnel has been driven into the mountain for some considerable distance on these properties but nothing very encouraging has been developed. In the tunnel are exposed some very coarse-grained and poorly cemented limestones and white marbles.

The following analyses by S. Shedd show the composition of the ore from these properties:

	No. 1.	No. 2.
Iron	62.45	68.54
Silica	5.78	1.89
Phosphorus .....	.....	.....
Sulphur.....	.21	.25

The analyses show the ore to be excellent in quality. It is uncommonly high in iron, low in silica and sulphur, with practically no phosphorus. Number one is from the surface about fifty yards from the tunnel. The question here again is quantity, and the indications are not very favorable for any very large body of ore.

CLEALUM DISTRICT.

ANALYSES OF IRON ORES FROM THE CLEALUM DISTRICT, KITTITAS COUNTY.

No.	Mine.	Iron oxide.....	Silica.....	Alumina and chromium oxide.....	Phosphoric acid.....	Sulphur.....	Iron.....	Phosphorus.....	Manganese oxide.....	Analyst.
22..	Emerson	15.58	67.28	1.92	.....	.....	47.10	.....	.....	Shedd.
23..	Hard Scrabble	14.00	68.38	6.02	.....	.....	47.87	.....	Trace	"
24..	Iron Monarch .	7.50	66.05	25.95	Trace	Trace	46.24	Trace	.....	"
25..	Roslyn.....	8.70	67.28	12.22	.....	.....	47.10	.....	.25	"
26..	Yankee.....	7.84	73.83	5.67	.....	.....	51.68	.....	.19	"
27..	Yankee.....	5.54	77.71	8.29	Trace	.....	54.40	Trace	.....	"
28..	Iron Monarch .	6.94	73.02	14.23	.....	.....	51.13	.....	Little	"
29..	Roslyn.....	5.68	86.40	4.80	.....	.....	57.12	.....	.....	"

THE MODE OF OCCURRENCE OF THE CLEALUM ORE.

The ore in this district occurs in the contact between a sandstone and serpentine as shown by Smith and Willis, in their paper read before the Washington meeting, February, 1900, of the American Institute of Mining Engineers. The ore outcrops along the valley at intervals, from about one-fourth of a mile south of Boulder creek to Camp creek, a distance of one mile and a half.

To the east of these outcrops along the river, and from 700 to 1,600 feet above them, is another line of outcrops, known as the Emerson group of mines. These have been traced for about a mile. The ore bodies are lenticular and vary in thickness from a few feet to thirty feet.

The following as regards their geological position is taken from the paper by Smith and Willis, already referred to :

"They have a definite geologic position in the rock series of the district, and their distribution is determined by the geologic structure. They lie on the surface of an extensive formation of serpentine at and in the base of a sandstone called the Swauk sandstone. The serpentine is older than the sandstone. It had been much eroded when the sandstone was deposited, and the sandstone, although composed chiefly of granito sand, contains in its lower beds, near the serpentine, bits of decomposed

serpentine and heavy minerals derived from it. Limited lenses of shale composed of serpentine wash and also conglomerates of serpentine boulders occur at the base of the sandstone. Thus the surface on which the iron ores occur was an eroded surface, which, with the soil and other residual accumulations, was buried beneath granite sands. The relations and character of the ore indicate that it was a sedimentary deposit on the serpentine, was covered by the sands, and later metamorphosed to its present condition."

The nearest place to these iron deposits where coal has been found, in any quantity at least, is Roslyn, and these coals are not coking coals, so that it would seem that in order to smelt these ores it would be necessary to ship them some place to fuel or ship the coke to them, either of which would be expensive.

CHARACTER AND COMPOSITION OF THE CLEALUM ORES.

The ores of this district vary considerably in appearance and general characteristics and range from a high grade iron ore carrying 57 per cent. of metallic iron on the one hand to a serpentine on the other carrying less than 10 per cent. of iron. These ores may be separated into three classes, as follows: Massive, laminated and oolitic. The massive ore has a dull, greenish black color and when powdered gives a brownish black streak. The laminated ore varies in appearance, in some cases being dark red and in others having considerable of a metallic appearance, but in each case giving a deep red powder or streak when pulverized. The oolitic ore has a greenish black color and contains numerous oolites in an amorphous ground mass and when powdered gives a brownish black streak or powder. All of these ores are quite strongly magnetic and are apparently mixtures of hematite and magnetite. In some of the ore bodies all three classes of ore are found and in others only one class. The oolitic ore, so far as I could determine, is not found in the ore bodies farthest up on the hill, high above the river, but is quite common in those down near the river and especially those near Camp creek.

The samples from which the analyses given here were made are thought to be average samples of the ores in this district, having been selected with a great deal of care by the writer himself, and while samples could probably have been found that would have shown a higher per cent. of iron, it is thought that these samples show the average of the larger part of the ore in the district.



CLEALUM MOUNTAIN.



GUYE IRON MINE, NEAR SNOQUALMIE PASS.



GEOLOGY OF THE CLEALUM IRON DISTRICT.

The geology of this district has been very carefully worked out by George Otis Smith and Bailey Willis of the U. S. Geological Survey, and a summary of their results has been given in a paper read at the Washington meeting, February, 1900, of the American Institute of Mining Engineers, and published in Volume 30 of their Transactions, and from that paper is taken the most of what is given here as regards the geology of the district.

Smith and Willis divide the rocks of this district into two groups and designate them as those which are older, or pre-Eocene, and post-Eocene. These two groups are unconformable, and the iron ore occurs in the contact between the two formations.

"PRE-EOCENE ROCKS.—The oldest rocks of the area are slates, chert, limestone, quartz schist, and volcanic breccias and tuffs, constituting a pre-Eocene complex. All these rocks have been somewhat metamorphosed, yet rarely to such an extent as to prevent the determination of their origin. They were folded, sheared, and intruded by igneous rocks early in the history of the region, and have been more or less mineralized with cupriferous, and argentiferous deposits.

"One of the most voluminous of the intrusives in the pre-Eocene complex consisted of large masses of peridotite, now more or less altered to serpentine. These intrusive masses are scores of miles in length and several miles in width. They have in great part the form and relation of large dikes.

"The youngest of the pre-Eocene rocks is a granodiorite closely resembling that of the Sierra Nevada. The rock looks like an ordinary medium-grained granite, except that it is poorer in quartz and slightly darker in color. It constitutes the Mt. Stuart batholith, and that mass with others in the Cascades furnished the sands of the Swauk sandstone.

"EOCENE AND POST-EOCENE ROCKS.—Arkose sandstone constitutes the great mass of Eocene strata in the Cascade range. They are of wide-spread occurrence on the west as on the east of the range. In the Mount Stuart district, the Eocene sandstones are divided by an extensive flow of basalt, and accordingly the Eocene formations are: first, the lower sandstone, which is called the Swauk; second, the Teanaway basalt; and, third, the upper sandstone, which is called Roslyn.

"The two sandstones are very similar in general character, and the eruption of basalt which flowed from conduits now represented by innumerable dikes in the Swauk sandstone, appears to have occupied a brief interval, after which the conditions of erosion and deposition were essentially the same as before it.

"The economically important facts of these Eocene rocks are the

occurrence of a good grade of steam coal mined at Roslyn, and the possibly valuable iron ores at the base of the Swauk.

"The post-Eocene formations are of both sedimentary and volcanic origin. Basalt flows, younger than the Teanaway basalt, connect with basalts which form the great expanse of the Columbia plain far to the east. A complex mass of more acid volcanic rocks, chiefly andesite, occurs in intricate relations with other formations about the head waters of the Yakima river, and overlying the Swauk sandstone west of the head waters of the Clealum river, forms the summit of Goat mountain."

The following analysis by S. Shedd shows the composition of the ore from the Emerson mine.

	<i>Per cent.</i>
Iron.....	47.10
Silica.....	15.58
Phosphorus.....	....
Sulphur.....	....
Alumina and chromium (Al_2O_3 and Cr_2O_3).....	1.92

The analysis shows the ore from this mine to carry a fair per cent. of iron, a rather high per cent. of silica, a small amount of alumina and chromium, and no phosphorus or sulphur, and is a fairly good iron ore.

The ore body in this mine is about 30 feet wide and the walls are serpentine. The ore is of a laminated character, and different parts of the ore body would vary considerably in the amount of iron contained, but it is believed the sample analyzed would represent fairly well the average of the whole body of ore in this mine so far as the present exposures are concerned.

The following analysis by S. Shedd shows the composition of the ore from the Hard Scrabble mine.

	<i>Per cent.</i>
Iron.....	47.87
Silica	14.00
Phosphorus.....	....
Sulphur.....	....
Alumina and chromium (Al_2O_3 and Cr_2O_3).....	6.02
Manganese.....	A little

The analysis shows the ore from this property to be very similar to the Emerson, which it joins.

These properties are situated on Magnetic point at an altitude of about 1,500 to 2,000 feet above the Clealum river at Camp creek. Some work has been done on these properties and the ore bodies uncovered for some distance. The occurrence of the ore in this property is also similar to the occurrence of the ore in the Emerson.

The following analysis by S. Shedd shows the composition of the ore from the Roslyn mine:

	<i>Per cent.</i>
Iron.....	47.10
Silica.....	8.70
Phosphorus.....	.....
Sulphur.....	.....
Alumina and Chromium (Al_2O_3 and Cr_2O_3)	12.22
Manganese.....	.25

The analysis shows the ore to be a little low in iron, free from phosphorus and sulphur and quite high in aluminum, but at the same time it is a fair grade of ore. The ore in this mine occurs under conditions similar to those under which the ore in the Iron Monarch, which it joins, occurs. The ore body is about ten feet wide and is about half of it oolitic ore and the other half laminated ore. The sample analyzed was an average of the laminated ore, and is seen to be very similar to the oolitic ore, with the exception that it does not contain more than half as much aluminum.

The following analysis by S. Shedd shows the composition of the laminated ore from the Yankee mine.

	<i>Per cent.</i>
Iron.....	51.68
Silica.....	7.84
Phosphorus.....	.....
Sulphur.....	.....
Alumina and chromium (Al_2O_3 and Cr_2O_3)	5.67
Manganese.....	.19

The analysis shows this to be a good iron ore. While it is true the per cent. of iron is not as high as it is in some iron ores, still it is above the average and then it is free from phosphorus and sulphur and does not contain a high per cent. of silica or aluminum. In this mine the oolitic ore does not occur but the laminated and massive ores do occur, and the sample was an average sample of the laminated ore. Some work has been done on this property and the samples taken were from the breast in the tunnel. The ore body in this mine is about fifteen feet wide and the laminated and massive ores are about equally divided.

The following analysis by S. Shedd shows the composition of the ore from the Iron Monarch mine.

	<i>Per cent.</i>
Iron.....	46.24
Silica.....	7.50
Phosphorus.....	Trace
Sulphur.....	Trace
Alumina and chromium (Al_2O_3 and Cr_2O_3)	25.95
Manganese.....	.....

The analysis shows this sample to be a little low in iron and to contain a very high per cent. of aluminum. While the aluminum and chromium were not separated, and the per cent. of each determined, the amount of chromium is not large and will probably not exceed 5 per cent. at the outside, so that there is probably 21 per cent. at least of alumina. The sample from which the above analysis was made is what has been described elsewhere as oolitic ore of a greenish black color and made up of round grains the size of mustard seed up to as large as a pea. These grains are embedded in an amorphous or finely-crystalline ground mass. The ore body in this mine is about ten feet wide and is about half of it this oolitic ore.

The following analysis, by S. Shedd, shows the composition of the massive ore from the Yankee mine:

	Per cent.
Iron.....	54.40
Silica.....	5.54
Phosphorus.....	Trace
Sulphur.....	.....
Alumina and chromium (Al_2O_3 and Cr_2O_3)	8.29
Manganese.....	Trace

The analysis shows the massive ore from this mine to carry a higher per cent. of iron than the laminated ore; it also has a higher per cent. of aluminum than the other, but not enough to interfere seriously with its smelting qualities.

The following analysis, by S. Shedd, shows the composition of the massive ore from the Iron Monarch mine:

	Per cent.
Iron.....	51.13
Silica.....	6.94
Phosphorus.....	.....
Sulphur.....	.....
Alumina and chromium (Al_2O_3 and Cr_2O_3)	14.23
Manganese.....	.87

The above analysis shows the massive ore from this mine to be higher in iron and lower in alumina than the oolitic ore from the same mine.

The following analysis, by S. Shedd, shows the composition of the highest grade massive ore found in the Clealum district:

	Per cent.
Iron.....	5 21/2
Silica.....	5 1/2
Phosphorus.....	.....
Sulphur.....	.....
Alumina and chromium (Al_2O_3 and Cr_2O_3)	4.80

The above analysis shows this to be a good grade of iron ore.

The following notes and analyses are from a manuscript report on the Clealum iron ores by R. H. Stretch, E. M.:

"The following is a report on eighteen sacks of ore taken at regular distances across the body with a view to get a fair sample of the quality at that point. The analyses were made by Professor Chas. F. Chandler and C. E. Pellew of Columbia college, New York.

Silica	10.28	Titanic acid.....	None
Iron	55.08	Sulphur.....	None
Alumina .....	.60	Carbonic acid.....	None
Lime.....	.53	Loss on ignition.....	5.30
Magnesia	1.48	Oxygen, alkalies, etc.....	26.6061
Manganese .....	.11		
Phosphorus.....	.0139		
			100.0000

"Another analysis of the ore tested at the Lanarkshire Steel Works, Motherwell, England, gave as follows:

Silica	5.41	Alkali.....	2.49
Ferric oxide	57.44	Carbonic acid.....	1.90
Ferrous oxide	15.58	Phosphoric acid.....	.161
Aluminum oxide	5.31	Sulphuric acid.....	Trace
Manganous oxide.....	1.65	Combined water	3.13
Oxide of nickel	2.98		
Oxide of cobalt	Trace		98.87
Chromium sesquioxide.....	2.12	Iron	58.32
Lime.....	Trace	Phosphorus.....	.025
Magnesia .....	.80		

"The table following gives the results obtained by Dr. Edward Riley, of London, England, whose standing as a consulting metallurgist and analyst can scarcely be said to be second to that of any expert in Europe, and who is almost as well known in the United States as in his own country :

No.....	Iron.....	Sulphur.....	Phosphorus..	Chromium ..	Oxides of Ni. and Co.....	Silica.....	Alumina.....	Magnesia.....	Oxide of Mn..
1...	49.55	Trace	Trace	2.04	1.20	7.65	9.16	3.87	Trace
2...	55.35	0.07	0.08	1.99	0.92	7.55	3.66	2.16	1.17
3...	51.66	0.05	0.02	2.06	0.90	5.85	8.30	3.26	None
4...	50.76	0.04	0.013	2.65	0.70	5.90	11.90	1.00	1.15
5...	52.26	0.04	0.016	3.18	1.10	6.10	5.40	2.75	1.25
Av.	51.916	0.04	0.0258	2.381	0.964	6.61	7.684	2.608	0.714
									1.138

GENESIS OF THE ORES.

Willis and Smith, in their paper already referred to, give the following hypothesis as regards the Clealum ores :

"SOURCE OF THE IRON.—The iron concentrated in the hematite and magnetite of the ore may be of extraneous origin or derived from an adjacent rock. In the facts of its position and association, there is no evidence to show that it is a deposit brought in from any more or

less remote extraneous source. There is much, on the contrary, to connect it with the serpentine. In its field relations, the ore lies on the serpentine, contains serpentine waste, and grades into shale derived from serpentine. The analysis of the ore and serpentine show that they both contain, in addition to the usual rock constituents, such occasional ones as chromium and nickel. Magnesia, an important constituent of serpentine, is also found in the ore. It is, therefore, reasonable to suppose that the iron ore is a result of concentration from the serpentine.

"**CONDITIONS OF DEPOSITION.**—The iron ore occurs on a surface of unconformity, the surface of the serpentine formerly exposed to the weather, and later buried under sands of the Swauk formation. In order to form a hypothesis of the conditions of concentration, it is necessary to interpret the facts of the unconformity.

"The basal-beds of the Swauk formation, other than the relatively limited occurrence of iron ore, are generally coarse arkose and more locally conglomerates, which consists of granite, greenstone and slate pebbles mixed, or of serpentine boulders alone, or rarely of granite boulders alone. The conglomerates are exceedingly local in extent, and when composed almost wholly of serpentine or granite are restricted to areas of those rocks underlying. The serpentine conglomerates contain only occasionally a granite pebble or one of any other rock than serpentine. The granite conglomerates contain a larger, but yet surprisingly small proportion of slate or quartz pebbles.

"These facts, taken in connection with the enormous volume of arkose which constitutes the Swauk and Roslyn formations, indicate that the conditions limited the transportation of boulders and shingle, but favored the accumulation of granite sands, and, furthermore that the localities where serpentine was weathering were for a time protected from the widespread deposits of arkose.

"The basal contact of the Swauk with the older formations is exceedingly uneven, and when traced out reveals the bold relief of the Eocene topographic surface, in which the soft shattered serpentine corresponded with lowlands. These depressions, which received little or no wash of other rocks than serpentine, may have been watersheds limited to areas of that rock. Here meteoric waters leached out the soluble parts of the disintegrated rock, and the mantle of residual material was deep. The climate was sub-tropic and vegetation abundant.

"As the coast of the rising water-body of the early Eocene time was established it assumed a very irregular outline, with numerous bays and promontories. The climate became favorable to very rapid disintegration of the granite, probably through slight hydration of the feldspar, without marked chemical change. At certain points along the coast, streams delivered the granite waste, which was built into beaches, spits and bars by shore currents. Behind the beaches and spits, lagoons were enclosed and, in some instances, such lagoons corresponded to shallow bays which received the drainage from areas of serpentine. That drainage was charged with iron and with decaying plants. The conditions were thus favorable for precipitation of iron either as ferrous carbonate or as

a hydrate of the sesqui-oxide in the shallow water of the lagoon. As the shore line of the slowly rising water-body advanced upon the land, the several conditions advanced with it, and in favorable localities a deposit of iron was a characteristic, and more or less extensive, basal deposit of the sediments. The conditions are believed to have been closely analogous to those which accompanied the deposition of the carbonate ores that have been dug in the Cretaceous formations about Baltimore, Md.

"CHEMICAL RELATIONS.—In connection with the hypothesis that the ore is the product of decay of the serpentine, a comparison of the analyses of the two is essential. The serpentine, of which the following is an analysis, was collected at some distance from the Clealum river locality, but fairly represents the rock at that point. It is here compared with the average sample of ore taken by Mr. Willis.

	Serpentine, Per cent.	Ore, Per cent.
SiO ₂	39.	7.5
TiO ₂	Trace.	.7
Al ₂ O ₃	1.75	21.9
Cr ₂ O ₃.....	.47	2.2
Fe ₂ O ₃	5.16	37.1
FeO.....	1.71	21.3
MnO.....	.15	Trace.
MgO.....	38.	2.3
H ₂ O.....	13.74	6.8
K ₂ O—No ₂ O.....	.10	Undet.
P ₂ O ₅	Trace.	.09
NiO.....	.10	.2
S .....	.03	.03
CO ₂	None.	.15
	100.21	100.27

"In comparing these two analyses we may consider the lean ore as a rearranged, but chemically little modified, residual product of the serpentine. In such comparisons most students of the subject of weathering have regarded alumina as the constituent least liable to removal, and therefore best adapted to serve as a basis of calculation.

"Supposing none of the alumina to have been lost in the course of the weathering of the serpentine, the alumina present in the residual product furnishes a measure of the amount of concentration involved in the process, and also of the amount of the material removed. In the present case, the alumina percentage having increased from less than two to nearly twenty-two, it would follow that twelve and one-half units by weight of the serpentine were required to furnish one unit of the residual deposit. Calculating the losses for the principal constituents it is found that the material removed has been in the main silica, magnesia and water. The approximate losses suffered by these constituents expressed in percentages are 96, 99 and 97 per cent., respectively. There is no apparent loss of ferrous iron, but in view of the probable interchanges of the two oxides of iron, the result may, perhaps, be expressed in terms of the iron itself, which shows a loss of 31 per cent. in the course of the decomposition of the serpentine into the residual

product. There were also small losses of manganese, chromium, phosphorus, nickel and the alkalies, many of these losses being large if expressed in terms of the amount present in the serpentine."

The amount of concentration as here shown by Willis and Smith may seem very large and almost unreasonable but there are cases on record* where serpentine weathered into a residual soil and, based on the amount of alumina, showed a concentration of nearly thirty to one. The two cases are quite similar but differ in the fact that in the soil the amount of silica is sufficient to combine with the alumina while in the iron ore there is more than enough alumina to combine with the silica and the alumina must therefore be present in the free or uncombined condition.

From the foregoing it is plain to see that Willis and Smith attribute the Clealum iron ores to the weathering and concentration of the serpentine in which they are found at present and that they are not contemporaneous with them.

COLVILLE AND VALLEY DISTRICT.

ANALYSES OF IRON ORES FROM STEVENS COUNTY.

No.	Mine.	Silica.....	Iron Oxide.....	Aluminum and Chromium Oxides.....	Phosphorus Acid.....	Sulphur.....	Iron.....	Phosphorus.....	Analyst.
37..	Silver King, Valley.....	1.66	96.51	....	....	.38	67.56	....	Shedd.
38.	Silver King, Valley.....	1.12	97.28	....	....	.25	68.10	....	"
39.	I. X. L., Colville.....	4.49	80.08	2.00	....	.72	.32	56.58	....
40..	I. X. L., Colville.....	14.90	72.12	2.48	.68	.32	50.48	.30	"
41..	Capital, Valley.....	5.80	84.55	1.85	.36	.33	59.19	.16	"
42..	Vigilant, Valley.....	3.54	83.62	3.18	.51	.21	58.53	.22	"

THE MODE OF OCCURRENCE OF THE ORES.

The general character of the region in which the iron ores of Stevens county occur, is that of a mountainous country with comparatively level valleys of considerable extent along the larger streams and the mountains rising gradually until an altitude of from 2,000 to 3,000 feet above the valleys is reached. The rocks of this region are limestones, shales, slates, serpentines, porphyries and marbles. The ores occur both in veins and in bedded deposits principally in the limestone and porphyry.

*Merrill: Rock, Rock-Weathering and Soil, p. 226.

CHARACTER AND COMPOSITION OF THE STEVENS COUNTY ORES.

The ores of Stevens county are principally hematites and limonites, and vary in appearance and texture from a very compact metallic-appearing mass to a finely divided loose red powder which has been used very successfully as a paint. Some of these ores again have small octahedral crystals of magnetite scattered profusely throughout the mass.

The ore from the Clugston creek district is a limonite or bog ore of a porous nature and ranges in hardness from a soft decomposed ore to a hard flinty ore. When pulverized it gives a brown streak and powder. The ores east of Valley are limonites having a deep red to almost black color, and when pulverized vary in color from a brown to dark red, indicating that in some cases at least there is some hematite present. The ores from west of Valley are hematites with some magnetite and vary in appearance from deep red to metallic. These ores when pulverized give a deep red streak and powder. The ores of Stevens county carry a high per cent. of iron, running from 50 per cent. to as high as 68 per cent. metallic iron.

THE CLUGSTON CREEK DISTRICT.—This district is about twenty miles north and a little west of Colville, T. 39 N., R. 37 E., section 11. The country rock in this district is a limestone and the iron ore seems to occur in masses, and not in a continuous vein, in the limestone and varies from well concentrated iron ore to limestone with very little iron ore in it. Two tunnels have been run on one of these properties, and at the end of the lower tunnel a shaft sixty feet deep has been sunk, so that a depth of 100 to 120 feet has been reached on this property. In the upper tunnel considerable ore was found, but in the lower one and in the shaft no ore was found. The ore in this district from present indications, so far as I was able to judge, is of very limited extent.

The following analyses by S. Shedd show the composition of the ore from the I. X. L. mine:

	Per cent.	Per cent.
Iron	56.58	50.48
Silica	4.49	14.90
Alumina	2.00	2.48
Sulphur.....	.32	.32
Phosphorus.....	.31	.30

The analyses show the ore to carry a good per cent. of iron and not an unusually high amount of sulphur or phosphorus and

to vary considerably in the amount of silica. The amount of phosphorus is too high for a Bessemer ore.

The following analyses by S. Shedd show the composition of the iron ore from the Silver King mine:

	Per cent.	Percent.
Iron.....	67.56	68.10
Silica.....	1.66	1.12
Alumina.....	.....	.....
Sulphur.....	.88	.25
Phosphorus.....	.....	.....

The analyses show this ore to be a very fine high grade iron ore. The samples analyzed were both from the same property. Some development work has been done on this property, a tunnel having been run in on the ledge for about forty feet, but as the hill has a comparatively gentle slope no very great depth has been reached. The country rock is shale, slate, limestone, and serpentine. The question of quantity is one that remains to be determined, as with the amount of work done it is not possible to tell very much as to the extent of the ore body.

The following analysis, by S. Shedd, shows the composition of the iron ore from the Capital mine:

	Per cent.
Iron.....	59.19
Silica.....	5.80
Alumina.....	1.85
Sulphur.....	.33
Phosphorus.....	.36

The above analysis shows the ore to be a good grade iron ore, a little high in sulphur and phosphorus for a Bessemer ore, however. This property is situated about two miles east of Valley, a small town on the Spokane Falls & Northern Railroad. The ore appears to occur in a bedded deposit and varies from a soft, loose, reddish mass to a hard compact ore, occurring in more or less concretionary or nodular masses. Considerable ore has been shipped from here to the Tacoma smelter and used as a flux in the smelting of other ores.

The following analysis, by S. Shedd, shows the composition of the iron ore from the Vigilant mine:

	Per cent.
Iron.....	58.53
Silica.....	3.54
Alumina.....	3.18
Sulphur.....	.21
Phosphorus.....	.51

The analysis shows this sample to be a good ore as far as the per cent. of iron it contains is concerned, but, like the preced-

ing one, to be too high in sulphur and phosphorus for a Bessemer ore. The occurrence of the ore in this mine is similar to that in the Capital. The sample analyzed was a finely divided, loose, uncompacted mass, and similar to the ores from this locality that have been used to a limited extent as a roof paint.

CONCLUSIONS.

Several things must be taken into consideration in determining the location of iron and steel industries or plants, the most important of which are the following: iron ore, fuel, fluxes, price of labor, and nearness to markets.

The preceding analyses show that Washington has some very high grade iron ores, but the question that has not been settled as yet is the one of quantity. In most of the districts of the state where iron is found so little work has been done that it is not possible to say positively whether the ore occurs in large quantities or not, and since the quality of the ore is good it would seem to be worth while to spend money enough in prospecting thoroughly some of the best districts to determine the extent of the deposits.

The Snoqualmie pass, the Clealum, and the Stevens county deposits are all situated long distances inland, and in most cases some distance from railroads. The Snoqualmie pass district, which contains the highest grade of iron ore, is about fifty miles from tide water and the Clealum district is about eighty miles, and no fuels near them except wood for charcoal. This would probably mean the paying of freight on them to tide water some place on the Sound, and unless the freight rate could be lowered very materially from what it is at the present time it would tend to prevent the using of these ores.

The question of good fuel is a very important one in the manufacture of iron and one that, so far as I can learn, has not been fully solved as yet in Washington. Charcoal makes a very high grade pig iron, but it is expensive and especially so where it has to be made from soft wood as it does here. Washington has large deposits of coal, some of which are coking coals, but the coke is not of the best quality, however, for the manufacture of iron. A good coke for iron furnaces should be low in ash, free from phosphorus and sulphur, and hard enough so as not to crush when charged into the furnaces. If it is high in ash it takes just that much more flux, as it has to be gotten rid of by this

means. As already stated, a very small per cent. of phosphorus or sulphur in a pig iron injures it for many purposes. If the fuel contains these substances they show in the pig iron the same as though they had been in the ore.

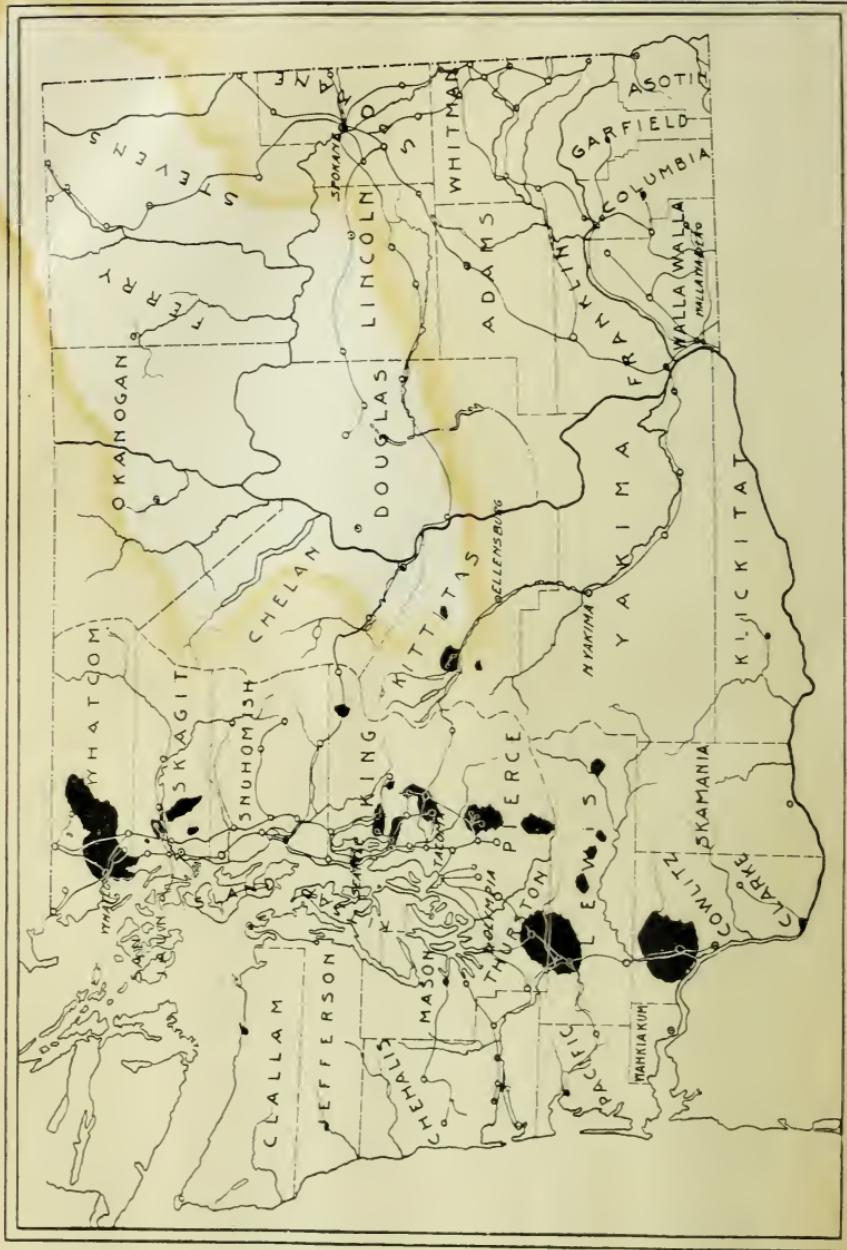
While analyses of the Washington cokes have not been made in connection with this report, the best data obtainable seems to indicate that they are high in ash and contain some phosphorus and sulphur. They are also soft cokes as compared with the best grades of coke for iron furnace work.

Washington has plenty of material suitable for fluxes and no fear need be felt in this particular. Labor is perhaps a little higher in Washington than it is in the East, but the difference would have very little effect on the price of iron. The whole Pacific Coast would furnish the market, as very little pig iron, if any, is being produced in any of the states west of the Rockies, except Washington, at the present time (March, 1902), and the steel and iron being used on the Coast is shipped from the East.

The results shown here are rather against the probability of Washington ever becoming a very large producer of pig iron from ores occurring within her own borders, at least, unless other deposits than those known at present are found. There is, however, one factor that has not been taken into consideration as yet, and that is the British ore occurring on Texada island and perhaps some of the other islands in the Straits of Georgia.

Number 7, in the table of analyses of Washington iron ores, shows the ore to be of very high grade, carrying 67.91 per cent. of iron, 2.96 per cent. of silica, 1.05 per cent. of calcium carbonate, and practically free from phosphorus and sulphur. This Texada ore is a heavy, black magnetite, and is said to occur in large quantities and is easy of access. The ore could be mined and loaded on boats or scows and transported to any place on the Sound at very small cost per ton.

If, on further investigation, it should be found that the Washington coke is suitable for use in the manufacture of iron, it is possible, perhaps, that by using the Texada ore alone, or by mixing it with the ores found in this state, that a considerable iron industry might be built up at some place on the Sound.



A MAP OF THE KNOWN COAL FIELDS OF WASHINGTON.

THE COAL DEPOSITS OF WASHINGTON.

BY HENRY LANDES.

INTRODUCTION.

The first authentic record we have of coal being found in Washington was in 1851, when some pieces of coal were picked up on the Stilaguamish river. Samples were sent to Washington, D. C., to be analyzed, and were found to be of good quality. Later investigations made by Rev. G. F. Whitworth showed however that the seams were too thin to be profitably worked.*

On Bellingham bay the first discovery of coal was made in the fall of 1852. Some work was done on the outcrop and about 150 tons were shipped, but by that time it was discovered that the coal was of poor quality and not in sufficient quantity to be of value, and it was therefore abandoned.

The next year, that is, in the fall of 1853, two men, Brown and Hewitt, discovered coal at Sehome. They were logging for the mill on Whatcom creek and found the coal where it had been uncovered by the uprooting of a large fir tree. They sent some of the coal to San Francisco for trial and a short time afterward received an offer of twenty thousand dollars for their claim, which they promptly accepted. For a number of years this was the only mine in the territory that was operated to any extent. It was finally abandoned a number of years ago.

In 1853 Dr. M. Bigelow found coal on Black river near Seattle. The vein was opened up and operated until the time of the Indian outbreak in 1855. Two of Bigelow's partners, Fanjoy and Eaton, were killed by the Indians and the mine was abandoned. Several attempts have since been made to re-open the mine but the coal contains too much dirt to make it profitable.

Early in the fifties coal was discovered on the Skookumchuck in the vicinity of the present town of Bucoda. The territorial

* Coal Mines of Western Washington, Rev. G. F. Whitworth. Resources of Oregon and Washington, Portland, Oregon, December, 1881.

penitentiary was located at this place and the convicts were employed for a number of years in the coal mine. When the penitentiary was removed to Walla Walla the mine was closed down.

Coal was also found on Clallam bay and was opened up in 1864 or 1865. The coal was of good quality but the vein was too thin to be profitably mined and so nothing has been done with it for many years.

In 1863 two very important discoveries of coal were made. The first was at Issaquah or Gilman, and the other a month or two later on Coal creek near Lake Washington, about where the town of Newcastle now stands. A number of Seattle men, including Daniel Bagley, G. F. Whitworth, John Ross and other well known pioneers acquired an interest in the property and began active development. The coal was first carried to Lake Washington in wagons, transported across the lake by barges, and then carried to Seattle in wagons. In 1867 the Lake Washington Coal Company, consisting of the above named gentlemen and others, was incorporated for the purpose of carrying on more extensive developments. A new opening was made and the transportation facilities improved. The coal was carried down Black river to the Duwamish, thence down the Duwamish to Elliott bay. Barges were first employed and afterwards steamers.

In 1870 the property was sold to the Seattle Coal Company. The new company immediately began to construct a tramway to Lake Washington from the mine and another from Lake Washington to Lake Union over the portage. A little locomotive and train of cars brought the coal from the mine at Newcastle down to Lake Washington, where the whole train was loaded on a barge and carried over to Union bay where it disembarked onto the portage tramway. After passing over the portage the train was loaded on another barge on Lake Union and taken to the point where the Western mill now stands. From there the train proceeded up town to the coal bunkers, which were situated somewhere on Pike street.

Early in the seventies Seattle was making determined efforts to secure railroad communication with the outside world. The Northern Pacific Railroad Company decided on Tacoma as its western terminus and showed a disposition to leave out Seattle

altogether. The citizens of Seattle therefore organized the Seattle & Walla Walla Railroad and Transportation Company and began a line of their own. They constructed the road to Renton and Newcastle and from that time forward the old portage route was abandoned.

Coal was discovered near Renton in 1873 by Mr. E. M. Smithers. Together with T. B. Morris, C. B. Shattuck and others he organized the Renton Coal Company for the purpose of developing the property. The coal was run down on tram cars from the mine opening to the Duwamish river where it was loaded on barges and towed into Seattle.

The Talbot mine was opened near the Renton Coal Company's property in 1874. John Leary, John Collins and J. F. McNaught, who had control of the property, organized the Talbot Coal Company. After a few years of operation they found their vein badly faulted and finally abandoned it.

Somewhere about 1862 or 1863 a gentleman named Mr. Van Ogle discovered coal in the canyon of Carbon river. He found it in such large quantities and over such a wide extent of territory that he concluded that a single claim would be of no particular value to him, so he did not interest himself any further in the matter. During 1874 and 1875 a large number of coal claims were taken and considerable prospecting done. In 1876 the Northern Pacific Railway built a line to Wilkeson and afterward to Carbon Hill. The original Wilkeson mine was abandoned after about three years operation.

The Green river coal field was discovered at a later date. Since that time new discoveries have been made in a great many different places, so that the limits of the known coal bearing rocks are being gradually extended.

GEOLOGY OF THE COAL MEASURES.

For the most part the coal seams of Washington occur interbedded in a series of light-colored sandstones and shales, with sandstones as the predominating rocks. The latter are usually bluish or grayish in color, but often weather into light buff owing to the oxidation of the iron carbonate which they contain. These rocks are not confined to the districts where workable coal seams are known to occur, but outcrop at intervals over the principal part of western Washington. In some places the strata are found

almost horizontal, but usually they are considerably folded and faulted and the upturned edges deeply eroded. Careful measurements of the series in the neighborhood of Puget sound, made by Mr. Bailey Willis, has shown a thickness of about ten thousand feet.

Carbonaceous matter is distributed in greater or less quantity throughout the rocks of the whole series. Small streaks of coal are found in most of the sandstones. The shales vary in color from light gray to black, according to the amount of carbonaceous matter present. All gradations are found between carbonaceous shale and pure coal. While the number of workable coal veins is small, being perhaps not more than ten or fifteen in any one district, the number of seams of more or less impure coal is very large, considerably over a hundred being known. All the veins thus far discovered which are clean enough and with the coal in sufficient quantity to be of commercial value are contained in the lower-most three thousand feet of the series. The upper two-thirds have thus far proven barren of workable seams, although rich in disseminated carbon. From the evidence of fossil leaves collected from various localities Professor F. H. Knowlton has determined these rocks to be of the Eocene age.

At the time these sediments were laid down the region between the present Cascade and Olympic mountains was a shallow sea or wide lagoon, more or less completely cut off from the ocean. That it was fresh or brackish water is shown by the character of the animal remains embedded in the sediments.* These are mostly unios or other fresh water forms.

During the whole of the long period in which these sediments were being deposited the region was undergoing a gradual but persistent sinking. The evidence of the coal seams in the lowest strata clearly shows that at that period the water at intervals was very shallow, and at the end of the period after sediments nearly two miles deep had been deposited the water still remained at about the same depth, showing that in the meantime the bottom of the sea had sunk two miles. These nicely adjusted forces of nature permitted the accumulation of a practically unbroken series of sediments throughout the whole period.

Subsidence did not take place at a uniform rate. There

* Invertebrate Fossils from Pacific Coast, C. A. White, Bulletin 51, United States Geological Survey, p. 56.

were periods during which the process of sedimentation shoaled the waters faster than the sea floor sank, and this continued until the water was shallow enough to support a swamp vegetation, which thereupon spread over the broad lagoons and flourished with great luxuriance. In regard to the climate, Professor F. H. Knowlton * says: "The lower beds, on account of the abundance of ferns, gigantic palms, figs, and a number of genera now found in the West Indies and tropical South America, may be supposed to have enjoyed a much warmer, possibly a sub-tropical temperature, while the presence of sumacs, chestnuts, birches and sycamores in the upper beds, would seem to indicate an approach to the conditions prevailing at the present day."

Alternating with the periods of coal formation, there were long lapses of time during which the water was too deep to admit of swamp growth. These were the times when subsidence proceeded at a more rapid rate than sedimentation, or at least kept pace with it. Sand and clay were then deposited. The final results of this intermittent, long continued subsidence was that we now have a large number of coal seams and layers of more or less carbonaceous matter interstratified with beds of sandstone and shale.

In order to maintain the water in a fresh or brackish condition either the outlet to the sea was very narrow or the climate must have been even more humid than it is at present. When we consider that notwithstanding the great volumes of fresh water being continually poured into Puget sound the water is not appreciably freshened it is difficult to account for the prevalence of fresh water forms in the Eocene sea except on the hypothesis that it was almost entirely cut off from communication with the open sea. The Olympic and Cascade mountains had not then risen to their present height but were probably rather in the form of low hills. The rocks of which they were formed were mostly of granitic type, as shown by the character of the sediments derived from them. The coal bearing rocks are known to occur along the western slope of the Cascade mountains from the northern border of the state southward to the Columbia river. It is probable that rocks of the same age form a rim around the foothills of the Olympics. Coal has been found in a number of places in

*Geological Atlas of the U. S., Tacoma Folio, U. S. Geol. Survey.

that part of the state, but owing to the very heavy forests and almost entire absence of roads very little is known about the region. Intermediate between the eastern and western parts of the field there was probably a nearer approach to marine conditions. Marine fossils found in Duwamish valley indicate that the border of estuarine conditions was somewhere between that locality and the coalfields to the eastward. The greater part of these fossils are identical with species found in the Tejon group of California, which is of Eocene age.*

VARIETIES AND USES OF THE COAL.

The coal is essentially a lignite in character. In certain limited localities, however, where great internal disturbance has taken place so that the coal has been crushed and rolled it has lost much of its volatile constituents and has become bituminous. The lignite is usually quite hard and breaks into more or less cubical forms. The bituminous coals are rather soft. They have been rolled out between their walls and thoroughly crushed, so that a considerable percentage of the volatile constituents have escaped and the coal is consequently richer in fixed carbon. The semi-bituminous or steaming coal lies midway between these two. Frequently the change from lignite to bituminous and back again occurs within the same vein.

The value of the coal depends upon the varying percentages of moisture, ash, sulphur, volatile hydro-carbons, and fixed carbon. In regard to the first three of these the smaller the percentage the greater will be the value of the coal. The ash is derived from two sources: 1st, the natural ash present in the plant from which the coal is derived; 2d, the dirt carried into the original coal swamp by streams and deposited with the coal. This latter source is usually by far the most important one. In a large number of coal seams it is the high percentage of ash rather than any other drawback which prevents the coal from being placed on the market. A number of representative analyses of coal from the principal mines show a range in the percentage of ash from 5.76 to 12.55. The samples from which these analyses were made were presumably taken so as to represent a fair average of the commercial article as it was placed on the market.

* Correlation Papers, Eocene, W. B. Clark, Bulletin 83, U. S. Geol. Survey, p. 108.

A high percentage of moisture detracts from the heating qualities of the coal because all the moisture has to be volatilized before any of the heat energy is available for any other purpose. The lignites of course contain more moisture than the bituminous coal and consequently have not such high heating qualities.

A certain percentage of volatile hydro-carbons is essential to coal. For steam generating purposes the semi-bituminous has been found to be the best. It has a representative analysis as follows: moisture, less than 5 per cent.; ash, 5 to 10 per cent.; volatile hydro-carbons, 30 to 40 per cent.; fixed carbon 40 to 50 per cent.

The Puget sound coals are suited to a variety of purposes. The output of some of the mines is used almost exclusively for steam generating purposes, as those of Franklin. Probably more coal is used for this purpose than for any other. A large quantity is used for domestic purposes. Coke making is becoming quite a large industry and several of the mines use a large part of their output in their coke ovens. The coke finds a ready sale, being more suitable for certain purposes. The only coal now used for gas making purposes is that found at Burnett. It is used exclusively in the Sound cities and in Oregon and California. It gives off a high percentage of illuminating gas and the residue cokes readily. A small vein of coal has been found at Fairfax suitable for blacksmithing and this finds a market at a high price.

Eastern Washington is largely supplied by the Roslyn mines which are the largest in the state. A considerable quantity of this coal finds its way to Seattle, where the company has recently erected large coal bunkers to take care of their export trade. A large part of the coal of western Washington is shipped to San Francisco and other coast ports. A considerable quantity is shipped to Alaska. The rise of the petroleum industry in California has caused a considerable falling off of the coal trade with the latter section. In the coastwise trade the coal of Washington competes with that of British Columbia and Oregon.

WHATCOM COUNTY.

In the western part of Whatcom county, extending from the foot of Mt. Baker to the coast, there is an area of Eocene coal

measures embracing over 250 square miles. These coal measures are composed mainly of massive sandstones and conglomerates, and shales, and are exclusively of lake origin. They have a total thickness of many thousands of feet. Within them very much vegetal matter in the form of lignite or coal is to be found, often in irregular masses or pockets, but now and then in a well-defined seam. Occasionally these seams assume dimensions sufficiently large to afford workable coal, and they are then of economic importance. In all cases, as far as known, the beds of coal are not immediately underlaid by clay, but by conglomerate or sandstone, showing that the coal was not formed by the plants which grew upon that particular spot, but rather that it was formed from drift wood. As a result no individual seam of coal can be expected to extend throughout the coal basin, or even over a large part of it, but is more local in its extent. It is also true that a coal seam will show considerable variability in thickness when followed in different directions.

Since their deposition the coal measures have been greatly folded and the strata are now inclined at high angles. Erosion has removed large portions of them, as may be seen in the wide valleys of the Nooksack and its tributaries, in the basin of Lake Whatcom, and elsewhere. In the eastern and central parts of the Whatcom coal field the strata outcrop everywhere and the coal beds may be easily found, but in the western part of the coal field the rocks pass under a heavy mantle of glacial drift and may only be studied or prospected by diamond drilling.

In the Whatcom coal field veins of workable coal have been found at a number of places. In some instances extensive mines have been opened and large quantities of coal produced. In a general way the coal may be said to improve in quality from west to east, as one passes from the region of least folded rocks to those that have suffered the greatest deformation. The coal vein now being developed on Cornell creek, within six miles of Mt. Baker, is said to be of a better quality than any other so far found in this field.

The Bellingham bay coal vein is the uppermost one in the Whatcom coal field. It is 14 feet thick, a lignite in quality, and was extensively worked 20 years ago. Its outcrop is north through the middle of the city of Whatcom and thence northwesterly, dipping west and southwest from 8 to 10 degrees.

Blue Canyon District.

The Blue Canyon mine is located on the southeastern shore of Lake Whatcom, on the railway of the Bellingham Bay Improvement Company. The vein of coal that is being worked varies much in thickness, but averages about 7 feet. It lies at the very base of the coal measures, being separated from the mica schist lying below by a layer of conglomerate which varies from six inches to three feet in thickness. Where the conglomerate is thinnest the coal vein is greatly broken and shattered, and is occasionally faulted. Lying as it does between the massive sandstones above and the metamorphic rocks below the vein has suffered greatly in the deformation of the coal measures. The vein pitches to the northwestward at an angle of 50 or 60 degrees.

The Blue Canyon mine has been in operation for a number of years, but has done little more than supply the demand of the cities and towns of Bellingham bay and thereabouts. The coal is very desirable for steaming and for domestic purposes. In 1901 the output of the mine was 48,200 tons.

SKAGIT COUNTY.

In the western half of Skagit county coal measures of Eocene age outcrop at a number of places. Surrounding these outcrops, as a rule, there are small coal basins, which seemingly have never been connected but have always been separated one from another. In the northwestern part of the county the large coal field of Whatcom county extends into Skagit for a little way. A mile west of Thornwood, on Samish river, there is an outcrop of coal where a little development work has been done. Immediately east of Montborne there is a small area of coal measures with a few coal outcrops. Near Cokedale and Hamilton there is in each case a coal measure area in which well known veins of coal occur.

The coal-bearing rocks above mentioned are composed essentially of shale, sandstone and conglomerate, with very much irregularly embedded vegetal matter in the form of lignite or coal. These deposits have been made in lakes which were enclosed in basins of metamorphic rocks, mainly schists and slates. After the lake sediments accumulated to a great thickness they were folded to such an extent that the strata are now often inclined at high angles. Since the disappearance of the lakes the

lacustrine sediments have been largely removed by erosion, and it is possible that the removal has been so great in the cases of the smaller lake deposits that some of these have not yet been discovered.

Cokedale District.

At the town of Cokedale a coal mine has been in operation for a number of years. The mine is located at the extreme northern limit of the coal basin, the lowest vein of coal being but a few feet from the schist which lies below. The coal measures of Cokedale outcrop along the northern boundaries of the district, but for the most part they are covered by the alluvial deposits of the Skagit river. The district is not believed to be a large one, extending from Cokedale southward to the Skagit, and in an east and west direction from near Lyman to a point a little way beyond Sedro-Woolley.

At the Cokedale mine three veins of coal are found, viz.: the north or Klondike vein, the middle vein, and the south vein. The north vein is the lowest one in the series and has a thickness varying from 10 to 25 feet; the middle vein lies 140 feet above the north vein, stratigraphically, and has a thickness of from 4 to 8 feet, with an average of 6 feet; the south vein, lying 40 feet above the middle vein, has a thickness varying from 6 inches to $2\frac{1}{2}$ feet. The north and middle veins only are worked at the present time.

The Cokedale coal veins at their outcrops stand about vertical, but in the lower mine workings they dip slightly to the southward. In the deformation of the coal measures the coal was so greatly broken that in mining it it is obtained only in small pieces, and never in large lumps. It is a good coking coal, and a large part of it is made into coke. The coal is all passed through washers after leaving the mine; the coarser part is then used for steaming and domestic purposes, while the finer part is taken directly to the coke ovens near by. The ovens are of the bee hive pattern, each having a capacity of five tons. Forty ovens are in place, ten of which were operated continuously during 1901. In 1901 the output of the Cokedale mine consisted of 12,643 tons of coal and 5,806 tons of coke.

Hamilton District.

A few miles east of the Cokedale district, and near the town of Hamilton, is a region of coal-bearing rocks known as the

Hamilton district. This district lies chiefly between Cumberland and Day creeks, and extends from the Skagit river to the neighborhood of Deer creek. The rock outcrops of the Cokedale and Hamilton districts, are separated by the broad alluvial plain of the Skagit, and it is not known at the present time whether the coal-bearing rocks extend from one district to the other.

At several places in the Hamilton district coal veins of commercial importance are known to outcrop. Upon some of these veins considerable development work has been done, and in times past some coal has been mined and sold. The coal is of good quality, and of a variety that may be made into coke. As a rule the coal veins lie in such a position that they may be worked very readily.

On the property of the Skagit Cumberland Coal Company and on the lands of Mr. J. J. Conner, near the mouth of Cumberland creek, there are a number of outcropping coal veins. The first of these is located on the bank of Cumberland creek, not far from the contact of the coal measures with the underlying mica schist. This vein of coal has a strike of south 43 degrees east, and a southwest pitch of 55 degrees. It lies between sandstone walls, and has a thickness of about seven feet of clean coal. About a hundred feet stratigraphically above the vein just mentioned, is a second coal seam having approximately the same dip and strike, with a thickness of over five feet. Above the outcrop of the number two vein, at varying heights on the mountain side, there are outcrops of several other veins of coal with thicknesses ranging from a few inches to four feet.

Toward the southern part of the Hamilton district, in the region about Day lake, coal outcrops at a number of places. In a few instances some development work has been done. In sections 13 and 24 T. 34 N., R. 6 E., the coal veins have a thickness varying from 8 to 12 feet.

KING COUNTY.

Newcastle-Issaquah District.

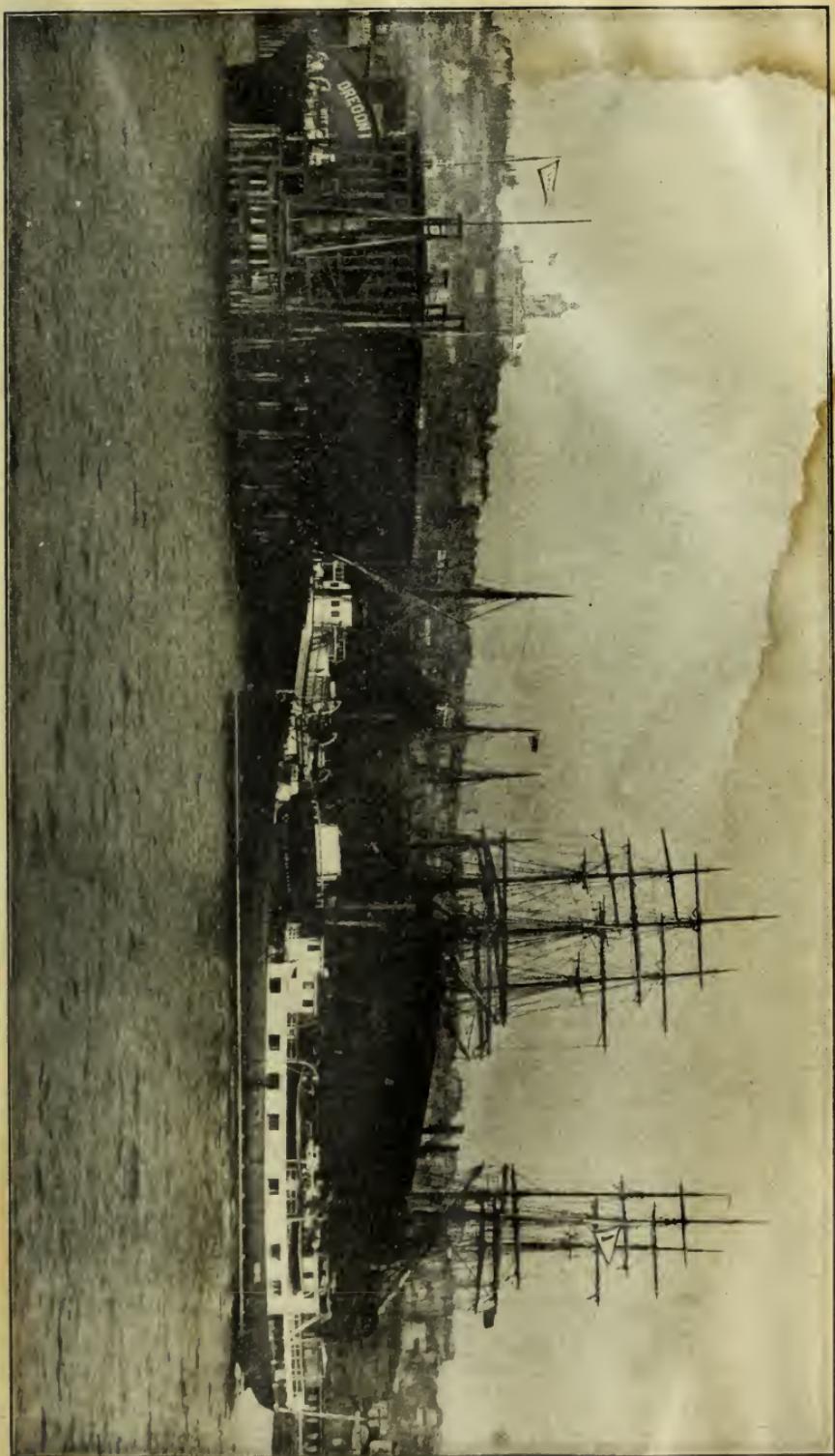
The Newcastle-Issaquah district probably constitutes one continuous coal field. The Issaquah mine, formerly known as the Gilman mine, is located at the northern base of Squak mountain, two or three miles from the southern end of Lake Sammamish, and about fifteen miles east of the city of Seattle.

Squak mountain is a mass of volcanic rock of the variety known technically as pyroxene andesite. The coal measures overlie the lava and dip to the northward at an angle of from twenty to forty degrees. The strike of the strata is nearly due east and west. Only one fault of any consequence has been encountered in the Issaquah mine, and that has not seriously interfered with the process of mining. In this mine the workings have been pushed westward through Squak mountain, under the valley of Tibbetts creek and into the Newcastle hills.

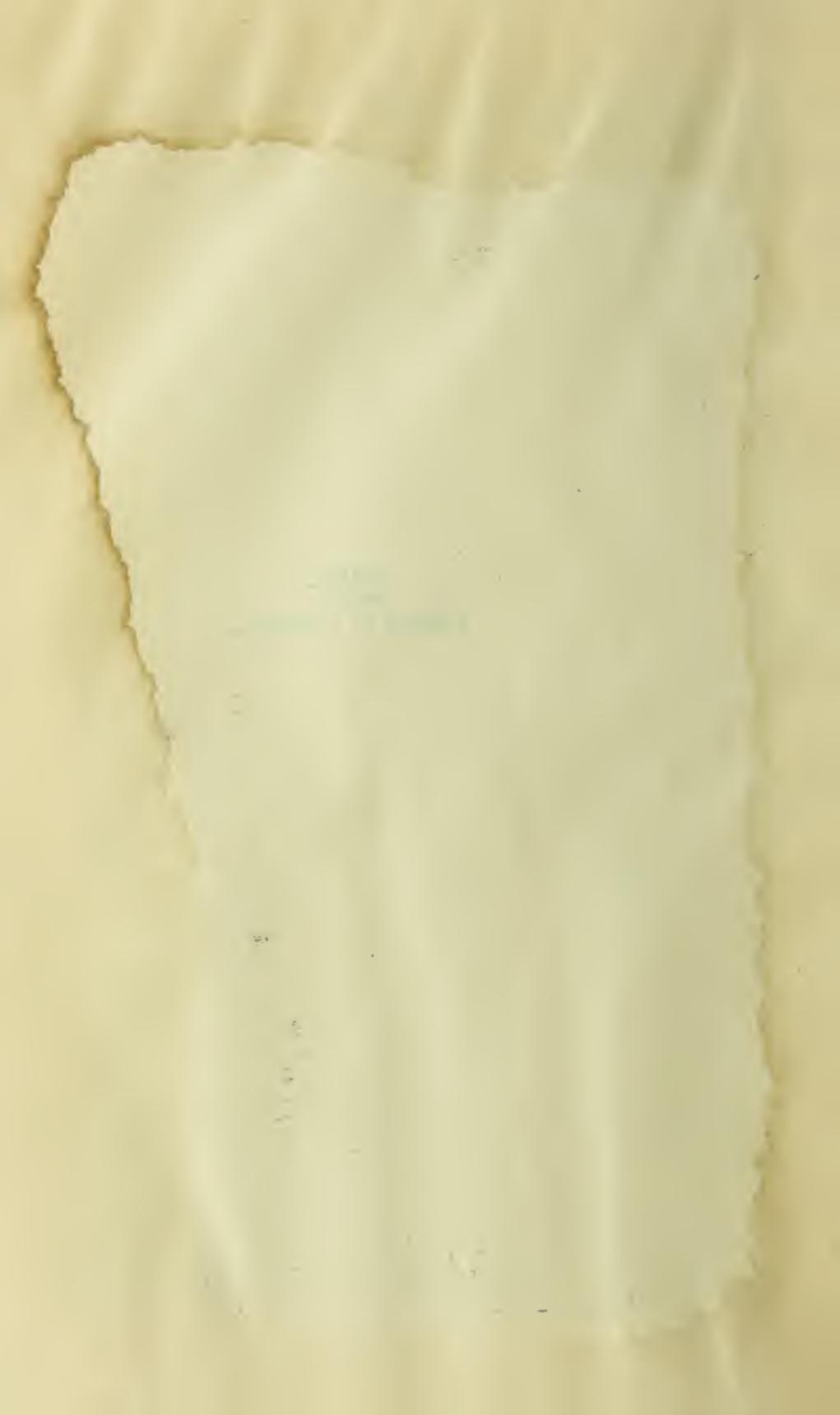
A branch line of the Northern Pacific Railway reaches Issaquah by way of the northern end of Lake Washington, and the coal is shipped by that route. The mine was opened by the Issaquah Coal and Iron Company in 1887. Their holdings embrace a tract of land five miles long by one and a quarter miles wide. Up to the present time they have worked out about three hundred and twenty acres of coal, and have produced altogether about 1,500,000 tons of coal. The output for 1901 was 121,829 tons. It is expected that the output for 1902 will be considerably larger. There are seven known veins of coal on the property having a thickness respectively of four, five, six, eight, nine, twelve, and fourteen feet.

According to the statement of C. F. Owen, State Inspector of Coal Mines, the coal generates very little gas and can be worked in safety with open lights. It is used very largely for steaming and domestic purposes.

On the Newcastle side of the mountain the principal openings have been made along Coal creek, a small stream flowing northwestward into Lake Washington. Most of the coal has come from the vicinity of the town of Newcastle, where it has been mined extensively for the last forty years. These mines are among the oldest in the Puget sound region and have up to the present time produced about five millions of tons. The coal is taken out by way of the Columbia & Puget Sound Railway, which reaches Seattle by way of Renton and the Duwamish valley. Both mines and railroad belong to the Pacific Coast Company, formerly the Oregon Improvement Company. The present Newcastle mine was opened in 1895, and is now practically worked out. It has produced altogether nearly 600,000 tons of coal. There are five veins, having a width of three feet four inches, four feet, four feet six inches, six feet and eight feet, re-



COAL BUNKERS, SEATTLE



spectively, and there are about ten miles of gangways and slopes. The breast and pillar system has been employed in the mine. Most of the coal is used for domestic purposes and for generating steam.

Since the Newcastle mine has been virtually abandoned active operations have been transferred to the new Coal Creek mine about a mile and a half farther up the stream. This mine was opened in 1898 and up to January 1, 1902 had produced about 300,000 tons. The daily output is now on an average 750 tons. For the year 1901 the total output was 130,957 tons. Four veins are being worked, two of them three feet eight inches in width, one four feet two inches, and one five feet. In the present workings the veins strike approximately east and west and dip north thirty-eight degrees. A double track working tunnel, seven by fourteen feet in diameter, has been driven a distance of 5,400 feet. There are altogether about three miles of gangways. In the main tunnel electric motors are employed for hauling, and electric lights are used. The breast and pillar system is the one adopted. A 375 h. p. plant generates electricity for hauling, lighting, ventilating, running the air compressor, running the washing machines, etc. The company uses a rotary washer of their own manufacture.

Renton-Cedar River District.

The depression occupied by Lake Washington is continued southward first as Black river valley, and then as White river valley. Less than a mile from where Black river leaves Lake Washington Cedar river enters the former from the eastward, flowing through a narrow, steep-sided valley for a number of miles and entering the broader valley at the town of Renton. Between the valleys of Cedar river and White river there is a plateau which from the surface indications seems to be composed entirely of glacial drift. It has an average elevation of about four hundred feet above the level of the bordering valleys. Along the steep sided northern and western edges of this plateau, especially near the town of Renton, the coal measures outcrop from beneath the covering of glacial drift. Seven or eight miles farther up the valley of Cedar river the coal-bearing rocks are again exposed where the Cedar mountain mine has been opened. On the northern side of Black river between

Renton and the Duwamish river the coal measures appear in a nearly horizontal position.

The first mine to be operated on an extensive scale in the vicinity of Renton was the old Renton mine, which was opened by a number of Seattle pioneers early in the seventies. This mine has long since been worked out, as has also the Talbot mine, opened a year or two later. In 1895 the Renton Co-operative Coal Company began operations on a tract of unoccupied ground between the two old mines. They afterwards sold out their property to the Seattle Electric Company. The new owners are now working on two veins, No. 2 and No. 3, each of which is about six feet thick, and they are driving a tunnel to open a third vein. There are about 9,000 feet of underground main tracks. The pillar and stall method of mining is employed. At present the daily output averages about 400 tons, and the total output for 1901 was 72,865 tons. The coal is used mostly for steaming and domestic purposes. It is washed by means of Howe washers. All the hoisting, pumping and lighting is done by means of a 150 h. p. electric plant.

Eight or nine miles up Cedar river from Renton is the Cedar mountain mine. The first openings in this vicinity were made about twenty years ago and for a long time the mine was a great producer, but the principal vein was lost and has only recently been rediscovered. The Cedar Mountain Coal Company obtained control of the property in 1898 and since that time has been working on an eight-foot vein. The total output for 1901 was 13,500 tons.

Green River District.

A thick section of the coal measures is exposed in the canyon of Green river, T. 21 N., R. 6 and 7 E. There are altogether forty beds of carbonaceous matter included in this section, but only four of them are productive coal beds. These outcrops were discovered about 1880, and two or three years later the Franklin and Black Diamond collieries were opened. The only vein that is now worked very extensively is the McKay vein, otherwise known as the Light Ash or White Ash vein. The strata in this district are thrown into long open folds, and the whole series inclines to the southwest. Several faults have been encountered in the course of mining and in each case the hanging wall has slid downwards. Three of these normal faults

occur in the Black Diamond mine. In the Franklin mine there are a number of small faults. In the eastern part of the field where the greatest disturbance has taken place in the rocks the coal has become highly bituminous, while in the northwestern section where the rocks remain more nearly in their original position, the coal remains a lignite.

The Gem mine at Franklin, belonging to the Pacific Coast Company, was opened in 1899 and has, up to date, produced 75,000 tons of coal. The total output for the year 1901 was 36,460 tons. It has now a daily output of 180 tons. The vein which the company is now working has a thickness of two feet seven inches of good, clean coal. In the present workings the vein strikes nearly due north and south and dips thirty-five degrees to the west. It is said that the vein can be traced for three miles on the surface of the ground. An estimate of the coal still to be mined places the amount at about 2,500,000 tons. The total length of underground workings is not far from 3,000 feet. A 75 h. p. steam engine is used for hoisting and ventilating. The chute and pillar system of mining is employed altogether.

The Franklin No. 1 and No. 2 was operated for a number of years, but was flooded and abandoned some time ago. It is now being reopened and will be operated again on an extensive scale in the near future. Since starting again it shipped, prior to January 1, 1902, 4,494 tons, and has now a daily output of 50 tons. Two veins are being worked, one four feet and the other nine feet in thickness. They are worked on the chute and pillar system. A 500 h. p. steam plant is employed for hoisting, ventilating, pumping, and operating the coal washing machinery. It also runs the air compressor, which is used for running the drills and other mining machines. The coal washers are of the rotary pattern and are the company's own manufacture. The coal is nearly all used on locomotives and steamers. The mine is the property of the Pacific Coast Company.

Franklin No. 7, opened in 1895, has produced about 700,000 tons of coal up to the present time and has now a daily output of 300 tons. The the total output for the year 1901 was 88,217 tons. One vein is being worked which has a thickness of four feet six inches. There is a 500 h. p. plant for hoisting, pumping, ventilating and lighting. The slope has now been driven in a distance of 3000 feet and there are altogether about five

miles of gangway. Electricity is used for lighting wherever possible. The breast and pillar system of mining is employed. The coal is used largely for steam generating purposes in steamers and manufacturing plants.

The Lawson mine near Black Diamond, which is also the property of the Pacific Coast Company, was opened in 1895 and has had a total output up to the present time of 260,000 tons. The company is working on vein No. 1, better known as the McKay vein, which is four feet and four inches in thickness, all of clean coal. There is now being mined on an average 400 tons per day. The coal is used very largely on steamers and in factories; also for domestic purposes. There are now three miles of underground gangways, and a slope fourteen hundred feet long. All the mining is done on the chute and pillar system. Steam power of 375 h. p. is used for operating the hoisting, ventilating, pumping and other mine machinery. Electricity is used for lighting wherever possible. It is estimated that the mine still contains about 5,000,000 tons of coal. For the year 1901 the output was 97,329 tons.

The Black Diamond mine was first opened about nineteen years ago. The property is now being operated from two openings on the McKay vein, known as Mine 14 and Morgan's Slope. The coal is good, clean steaming coal and requires very little picking or washing. It produced in 1901, 227,000 tons.

The Seattle & San Francisco Railway Company's mine at Ravensdale, formerly known as Leary, was opened two or three years ago when the district was given transportation facilities by the construction of the Palmer cut-off of the Northern Pacific railway. It is situated seven or eight miles west of Palmer. Four veins are now being worked. Prior to 1901 the mine shipped 48,000 tons and for 1901 the total output was 63,578 tons. The company has lately constructed large coal bunkers at West Seattle.

PIERCE COUNTY.

Wilkeson-Carbonado District.

This field lies about midway between the city of Tacoma and Mount Rainier. All of the producing mines are in the extreme northern part of the field and not far from the main line of the Northern Pacific Railway. Carbon river, which derives its name from the numerous outcroppings of coal along its course, flows

for about eight miles through the district. Just above the town of Carbonado the river flows through a steep sided canyon in volcanic rock, but at the town and for a mile or two down the river the coal series is exposed. Other sections occur along Gale creek and South Prairie creeks, tributaries of Carbon river. The hills are covered with glacial drift to a depth of from fifty to three hundred feet. In addition to this the whole region is very heavily timbered, so that surface prospecting can be carried on only along the stream channels. Measurements made by Mr. Bailey Willis,* of the sections exposed along the streams and in the mine workings showed a thickness of 8,000 feet of barren measures lying above the productive coal beds.

Coal was first discovered on Carbon river forty years ago, and the first location was made by Flett Brothers and their brother-in-law Gale, about ten or twelve years later, that is, in 1874. They made the first opening on Gale creek about half a mile above the present town of Wilkeson. A wagon road was constructed from South Prairie to the mine and a number of tons of coal hauled to Tacoma.

The Burnett mine is the most northerly one now operated in this field. It was opened by Mr. C. H. Burnett in December, 1881, and has now passed into the hands of the South Prairie Coal Company. A short branch line connects the mine with the Northern Pacific Railway at Cascade Junction. Four veins have been worked to a greater or less extent, but there are only two at present from which coal is being taken. They are both about three feet in thickness. The total output since the mine was first opened is estimated at 930,000 tons. At the present time about 300 tons per day are being shipped. The total length of underground workings is at least two miles. The coal is used for domestic purposes, for steaming, and for the manufacture of gas. The coal is washed by means of Howe washers. A 300 h. p. steam power plant is employed for hoisting, pumping, etc. Seventy-seven thousand two hundred and fifty-five tons were produced in 1901.

The Wilkson mine, operated by the Wilkeson Coal and Coke Company, is on a branch line of the Northern Pacific railway about thirty-one miles from Tacoma and two miles south of Burnett. It was opened in 1879 and at the present time there are

* Willis: Coal Fields of Puget Sound, 18th Ann. Rep. U. S. Geol. Survey.

about six miles of water level gangways. The estimated total output since the mine was started is 1,000,000 tons. The daily output now is 500 tons. Six veins are being worked, having an average thickness of six feet each. The chute and pillar system of mining is employed. Forrester patent washers are used. The power consists of two steam stationary engines of 130 h. p. and two locomotives. Mules are employed underground. The company has a large coking plant in operation and most of the output of the mine is converted into coke. There are fifty ovens built on the bee hive pattern, twelve feet in diameter, which turn out about seventy tons of coke per day. Fifty more ovens are being erected which will give a total daily output of 100 tons. In the year 1900, 47,615 tons of coal were converted into 29,309 tons of coke. For the year 1901 the total output was 125,028 tons of coal. The veins which are now being worked outcrop on the surface along Gale creek in the western part of section 27. The strata here are bent into a broad, low arch with a number of smaller folds. Operations have been conducted on each side of the main arch and a number of faults have been encountered. The present company operating the mine owns the land on the western side of the arch. On the eastern side where the veins dip to the eastward the land belongs to the Northern Pacific Railway Company, but is worked by the Wilkeson Coal and Coke Company on a royalty in connection with their own property. Only one quarter of the available coal above water-level has been worked out and there are several millions of tons below water-level that can be mined at a profit.

The Carbonado mines are opened about two miles south of Wilkeson on Carbon river, which here flows through a canyon about three hundred and fifty feet deep. The railroad was extended from Wilkeson to Carbonado about the year 1880 and shipments of coal at once began. Four veins are now being worked which have a thickness of four feet six inches, five to six feet six inches, five feet, and seven feet four inches respectively. The total output has been over four millions of tons. The output for 1901 was 323,395 tons. A battery of 75 coke ovens is being installed.

The Gale Creek Company and the Willis Coal Company are opening up new mines in the district. The Gale Creek Company is working five veins from three to seven feet thick, and

has taken out about one hundred thousand tons of first-class steaming and gas coal. Their output for 1901 was 18,900 tons. The Willis company has six veins, from three to six feet thick, and has taken out several thousand tons.

The Western America Company, operating the Fairfax coal mine, has built a railroad seven and a half miles long to connect with the Northern Pacific at Carbonado. They began operations in January, 1900, and are now producing about two hundred tons per day. For the year 1901 their output was 30,513 tons. Three veins are being worked: No. 2, six feet thick, No. 3, six feet eight inches thick, and Blacksmith vein, two feet six inches thick. A water-power plant of 125 h. p. is used to generate electricity for lighting, hauling, etc. There are now about 3,000 feet of gangways with smaller workings to match. The diamond system of mining is principally employed. The company has gone into the coking industry on an extensive scale. They have now in operation sixty bee-hive ovens thirteen feet in diameter and seven feet in height. Besides being made into coke, the coal is very largely used for blacksmithing and for steam making.

The Montezuma mine has been opened in section 2, T. 17 N., R. 6 E. Work was begun in February, 1901, and up to the present time about 800 feet of entries and airways have been driven. No attempt has yet been made to stope out the coal and no shipments have been made, but in the course of driving the entries from twenty-five to thirty tons of coal per day are taken out. The long wall system of mining will be employed. The company has ordered one hundred bee-hive coke ovens and as soon as these arrive most of the output of the mine will be converted into coke. A 400 h. p. turbine wheel has been installed, and all the hoisting, hauling, etc., will be done by water power. Three veins are being worked, having a thickness of three feet six inches, seven feet and nine feet, respectively. Two rock tunnels are being driven which will crosscut two or three more veins, one five feet, one nine feet and another of unknown thickness.

KITTITAS COUNTY.

Roslyn-Clealum District.

The Roslyn and Clealum coal field, situated in the north-western portion of Kittitas county, on the line of the Northern

Pacific Railway, is separated from the coal fields of western Washington by the main range of the Cascade mountains.

The coal occurs in a series of light colored sandstones to which the name "Roslyn sandstone" has been given. This formation is underlaid by a series of sheets of basaltic lava, which in turn are underlaid by other sandstones. The thickness of the Roslyn sandstone has been estimated as at least 3,500 feet.* Fossil plants from the Roslyn coal mine and from other coal seams about Clealum have been identified by Professor F. H. Knowlton as being of Eocene age. This makes the Roslyn coal roughly contemporaneous in origin with the coals of western Washington.

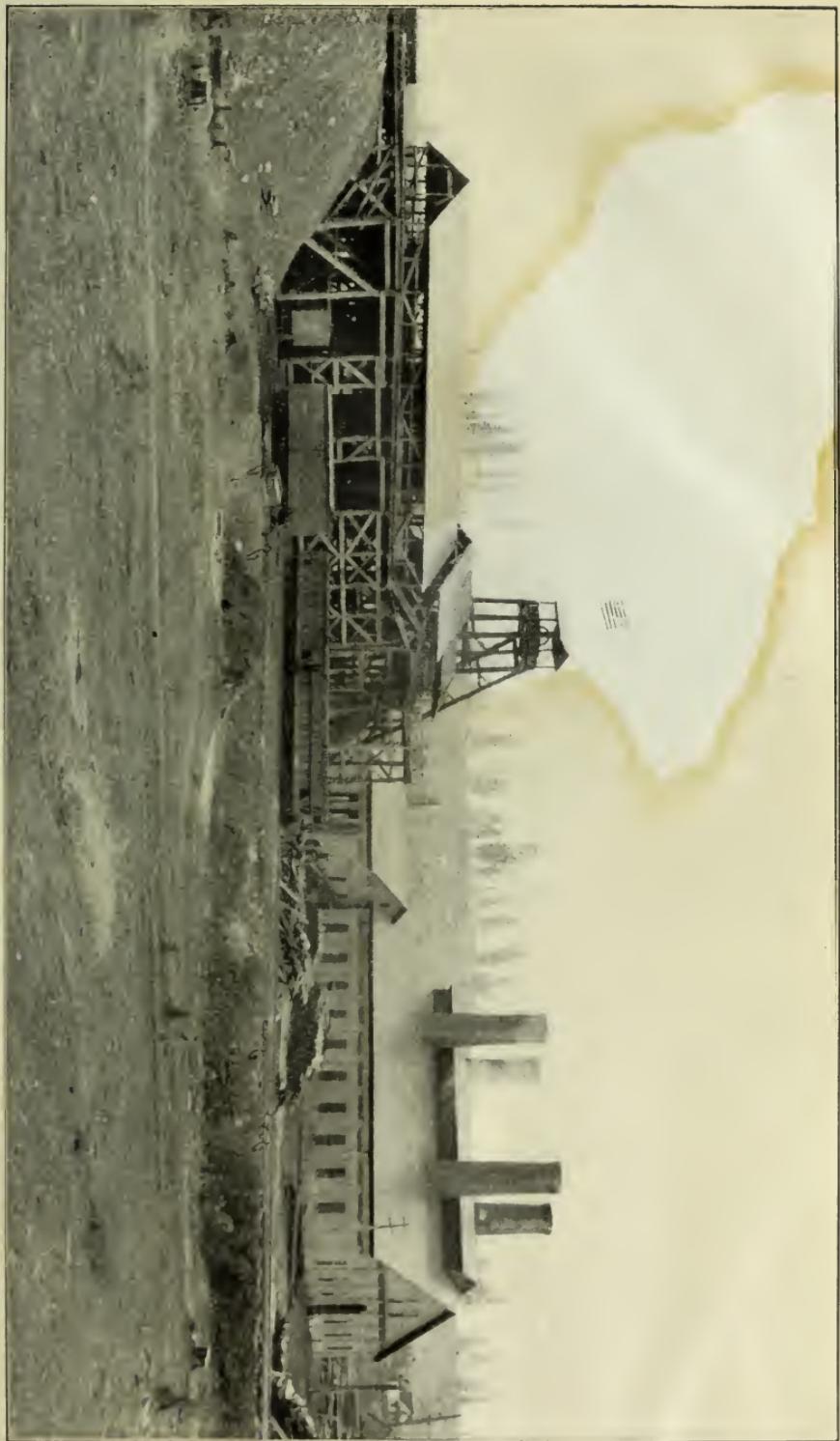
The Roslyn coal mine, owned and operated by the Northwestern Improvement Company, is the largest in the state. A branch road three or four miles long runs from the main line of the Northern Pacific Railway at Clealum to this mine. The mine was first opened in 1885 by the Northern Pacific Coal Company, which was afterwards reorganized as the Northwestern Improvement Company. The coal vein is four feet eight inches in thickness and dips at Roslyn from thirteen to twenty-six degrees to the southwest. It is bituminous and an excellent steaming coal. The output for 1901 was 1,005,027 tons, having a value at the mine of over \$1,500,000. Up to November 1, 1901, the total output since the opening of the mine was 5,826,727 tons, taken from an area of about one thousand acres. A conservative estimate of the Northwestern Improvement Company's holding of ten thousand acres places the total amount of coal still remaining at forty-seven millions of tons.† The Roslyn vein is supposed to extend under the entire Clealum valley at a depth of eleven hundred to fifteen hundred feet. It occupies a shallow syncline with an east and west axis.

The Clealum mine, operated by the same company as the Roslyn mine, was opened in 1894. The vein upon which they are now working occurs higher in the series than the Roslyn vein. It is from four and one half feet to five and one half feet thick and dips southward at an angle of about fourteen degrees.

The Ellensburg Coal Mining Company has operated a mine

* Geology of the Cascade Mountains in Northern Washington, I. C. Russell, 20th Ann. Rep. U. S. Geol. Survey.

† 9th Biennial Report, State Inspector of Coal Mines, C. F. Owen, 1901.



NO. 4 OPENING AND ELECTRIC LIGHTING PLANT AT ROSLYN COAL MINES.

in a small way situated two miles north of Clealum. The vein is four feet thick.

Other coal outcrops occur on the Teanaway river north of Clealum, on Frost creek, on First creek, Naneum creek and on Williams creek.* Not much development work has been done on any of these properties, so it is not known at present whether or not the coal occurs in commercial quantities.

THURSTON COUNTY.

Bucoda-Tenino District.

The Bucoda-Tenino district lies in the southern portion of Thurston county. Its boundaries are not definitely fixed in any direction. A large part of its surface area is composed of flat river bottom and barren gravel plains, and it is only where the coal-bearing formation appears at the surface along the hillsides and on higher ground that it is possible to discover any outcroppings of coal.

Coal was first discovered in the valley of the Skookumchuck in 1855. It was mined in the vicinity of Bucoda in early territorial days, the convicts of the penitentiary being employed for that purpose. The early mines are now closed down and it is difficult to get definite information regarding them.

The Chehalis and Skookumchuck rivers flow through wide, level valleys. Hills of sedimentary rocks belonging to the coal-bearing series border the valleys and rise to heights of several hundred feet. During late glacial time the melting of the great ice mass which occupied the basin of Puget sound caused a tremendous flood of water to sweep southward over this region. This great river was heavily loaded with sediments of all degrees of coarseness, which it dropped by the wayside as it passed along. In the northern part of the field in the vicinity of Tenino the gravel is quite coarse, and water-worn boulders are scattered everywhere. Traveling southward into Lewis county the material gets finer and finer until in the vicinity of Chehalis it is a fine sandy loam with no gravel. South of Chehalis there are no signs of glacial action whatever.

The Great Western Coal Company, of Spokane, have a mine about four miles southwest of Tenino in section 35, T. 16 N., R.

*Geology of the Cascade Mountains in Northern Washington, I. C. Russell, 20th Ann. Rep. U. S. Geol. Survey.

2 W. Considerable prospecting work has been done with a diamond drill. A tunnel three hundred feet long has been driven and crosscuts made. The vein upon which they are working is about three feet six inches in thickness. At the present time the coal is hauled to the railroad in wagons, and about two car loads a week are shipped. The coal is said to be of good quality. It is a lignite like all the rest of the coal in this field.

The Seatco coal mine was opened in 1880 near the town of Seatco, the name of which was afterwards changed to Bucoda. It was operated with convict labor taken from the territorial penitentiary, which was at that time located at Seatco. Public sentiment was hostile to the enterprise, however, so that the convict system was soon discontinued and the mine closed down. Of the original penitentiary company, composed of Messrs. Billings, Smith and Shead, Mr. Billings is the only surviving member. They operated on an eight foot vein of coal and took out altogether about ten thousand tons.

LEWIS COUNTY.

Chehalis-Centralia District.

The two towns of Chehalis and Centralia lie about four miles apart, on a wide river plain. Along the sides of the valley coal outcroppings have been found and a number of openings have been made, but none of them have developed into extensive mines. A little coal is being taken out to supply the local demand. Nearly all of it is used for domestic purposes. The electric power plant of Chehalis uses it for making steam.

In the hill back of the town of Chehalis a number of prospects have been opened up in the past. Several years ago prospects were opened up on the Rosenthal property, but they have since been closed. At the present time there is one small mine working about a mile from town in Sec. 29, T. 14 N., R. 2 W. It is operated by Miller Brothers. They have driven a tunnel about one hundred and twenty feet on a vein which measures four feet three inches in thickness and dips about forty-five degrees. They began work in October, 1901, and at the end of the year had taken out about four hundred and thirty tons. The coal is all sold in the town of Chehalis. It is a lignite of fair quality, but leaves a large amount of ash.

There is only one coal mine operating at present in the vicinity

of Centralia. It is the Salzer Valley Coal Mine, situated in Sec. 22, T. 14 N., R. 2 W., about four miles east of Centralia. This mine has been operated in a small way by Mr. Marion Howell for the last four years. For the last three months of the year 1901 the output was 267 tons. The vein is five feet six inches in width and lies nearly horizontal. A tunnel one hundred and fifty feet long has been driven. The coal is hauled in wagons to Centralia and Chehalis and sold for domestic purposes.

A new mine is being opened up by the Sterling Company in the Hanaford valley in T. 14 N., R. 1 W., about eight miles east of Centralia. A railroad will be built from the mine to the Northern Pacific Railway, a distance of a little more than nine miles. The junction will be about a mile and a half north of Centralia. The company owns nine hundred acres of coal lands. Three veins will be worked, the first seven feet four inches thick, the second fourteen feet thick, and the third five feet eight inches thick. The coal is a lignite and is said to have a low percentage of ash. At the point where the veins are being opened up they dip about eleven degrees from the horizontal.

The old Florence or Ellsbury mine is now closed down. It was worked for a number of years and had a total output of about ten or fifteen thousand tons. It was finally abandoned seven or eight years ago.

Some coal was taken out of another mine on Sec. 3, T. 14 N., R. 2 W., but it was also abandoned about four years ago.

To the eastward coal outcrops have been found at intervals nearly all the way to the summit of the Cascades. At several different places extensive development work has been done. In the western part of the field the coal is lignite, but as it approaches the Cascades it is said to develop into bituminous coal and finally into anthracite.

COWLITZ COUNTY.

Kelso-Castle Rock District.

The Kelso-Castle Rock coal field embraces nearly all of the northwestern part of Cowlitz county. The Cowlitz river runs north and south through the center of it. The country is, for the most part, very heavily timbered and the hills are worn into low, rounded forms so that the solid rock does not show in many places. The soft coal bearing rocks have been decomposed to

considerable depths and a residual soil many feet in thickness has been formed. For this reason the boundaries of these rocks are not definitely known. It is probable that as the district becomes better known the boundaries of the area of productive coal measures will be greatly extended.

Throughout this part of its course the Cowlitz river flows through a flat alluvial valley a mile or two in width, bordered by low hills which gradually increase in height as they recede from the river. The tide flows up the river several miles above Kelso. At Rocky Point and at Castle Rock bold bluffs of hard basaltic lava extend out into the valley. In the vicinity of Kelso and higher up the river there are the remnants of a rocky bench or terrace about fifty feet in height above the level floor of the valley.

The coal bearing rocks are sandstones and shales probably of Eocene age. They have been upturned from their original horizontal position only to a slight degree. Along the Cowlitz river the rocks are thrown into gentle folds. A large number of coal seams have been found at different places varying from a few inches to six or eight feet in thickness.

The Anchor mine was opened in 1890 by the Anchor Coal and Development Company, of San Francisco. It is located in Sec. 13, T. 8 N., R. 2 W., about three miles northeast of Kelso. Two veins were worked, one about four feet and the other five feet in thickness. A narrow gauge railroad three-quarters of a mile long ran from the mine to the Cowlitz river where the coal was loaded on barges and shipped to Portland and other places. Although a large amount of money was spent, the mine did not turn out to be a success. It was finally abandoned about 1898.

The Coal Creek Development Company, of The Dalles, Oregon, is opening up a coal prospect on Coal creek, about eight miles west of Kelso. A standard gauge railroad is being built from the mine to tide water, a distance of four miles, where the coal will be loaded on barges and shipped to Portland.

The Oregon Coal and Timber Company, Joseph Gaston, president, W. T. Webber, superintendent, has obtained possession of the old Idleman mine, situated in Secs. 12 and 13, T. 9 N., R. 2 W., about a mile and a half east of Castle Rock. The mine was first opened up by Mr. C. M. Idleman, a number of years ago. It was worked in a small way until 1893, when it closed down on account of litigation. The new company began

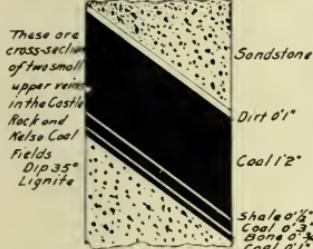
operations late in the autumn of 1901. The old workings have been pumped out and preparations are now being made to develop the mines on an extensive scale. Several veins are being opened up, one four feet six inches, another four feet one inch, and a third six feet in thickness, respectively. Still other veins of unknown thickness outcrop at points below. A standard gauge railroad from the mine to the Cowlitz river is partly completed. An incline seven hundred feet in length has been driven and a number of crosscuts made. The coal is a brown lignite with very little sulphur and a small percentage of ash. It will be shipped in barges to Portland.

Another mine known as the Red Ash mine was opened up several years ago on Arkansas creek, about two or three miles west of Castle Rock. A considerable amount of coal was shipped to Portland and other places, where it is said to have given good satisfaction. It was closed down about two years ago, but negotiations are now pending whereby it will be opened again. The vein that was worked is said to be seven feet in thickness. A shaft has been sunk and an incline one hundred and fifty feet in length driven on the vein.

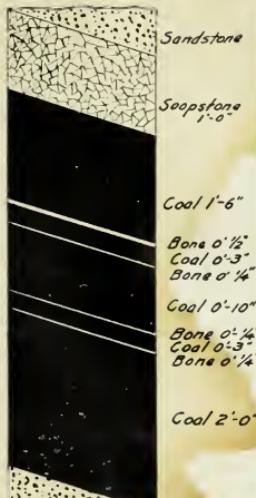
The Carbondale mine, three miles southeast of Castle Rock, in Sec. 24, T. 9 N., R. 1 W., has been developed to some extent. It belongs to Portland parties. No coal has yet been shipped from this prospect.

Another prospect upon which work has been done lies in the NW. $\frac{1}{4}$ Sec. 24, T. 10 N., R. 1 W., on Toutle river, three or four miles from the Cowlitz. Other prospect holes have been sunk on Sec. 24, T. 9 N., R. 1 W., and in Secs. 8 and 18, T. 10 N., R. 1 E.

CASTLE ROCK



ROSLYN



BLUE CANYON



CASTLE ROCK

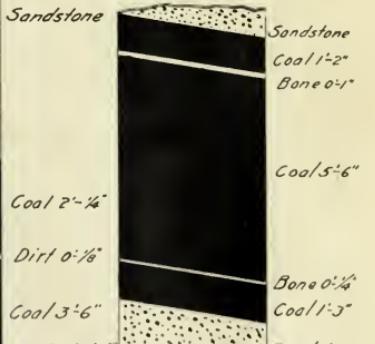


SNOQUALMIE

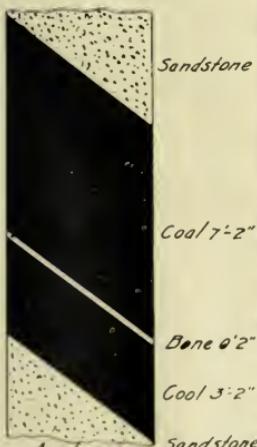


Analysis
Fixed Carbon 60.96
Volatile Matter 28.74
Moisture 0.35
Ash 9.95
100.00

BUCKDALE



NEWCASTLE



Analysis
Fixed Carbon 43.90
Volatile 46.70
Moisture 2.12
Ash 7.28
Sulphur .000
100.00

a-Dirt 0' 1/2"
b-Coal 2' 0"
c-Sandstone
Analysis
Fixed Carbon 60.53
Volatile 29.12
Moisture 3.92
Ash 6.10
Sulphur 0.33
100.00

Miblock's Mine Raging River

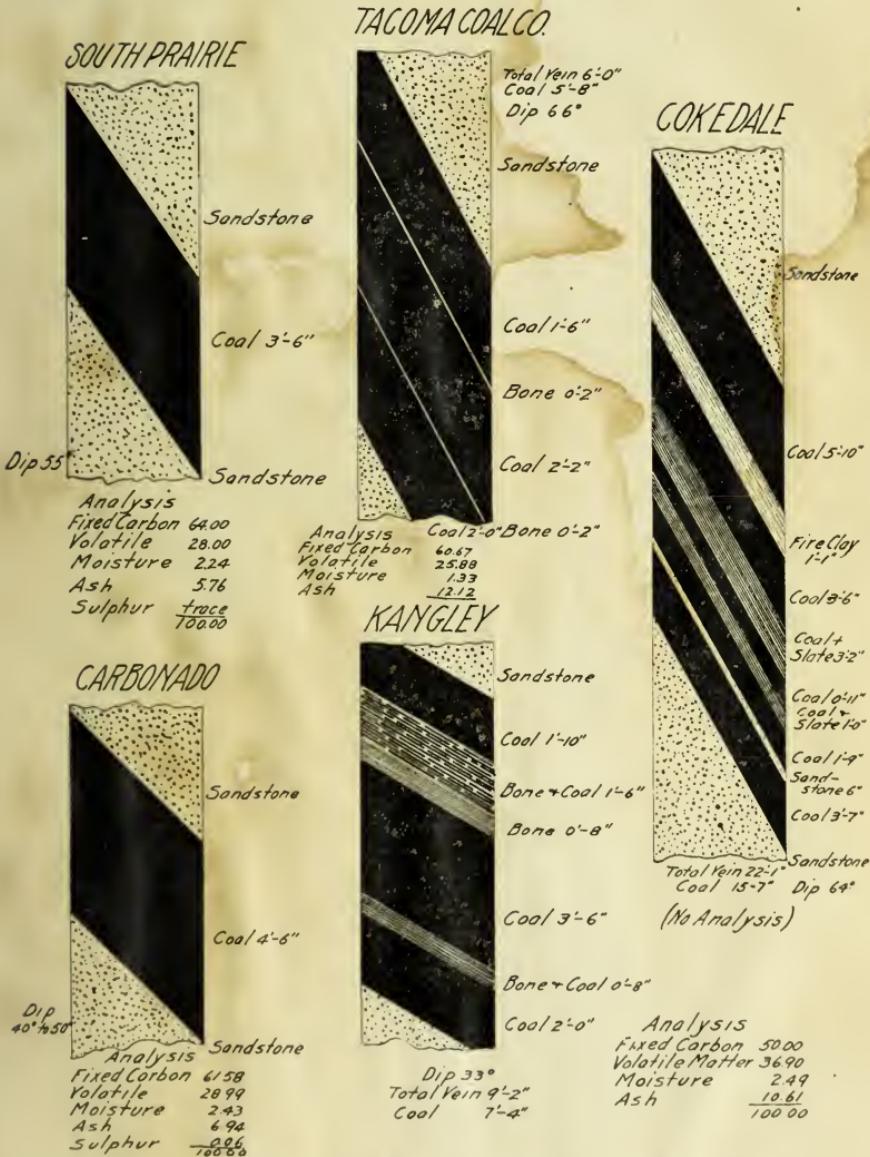
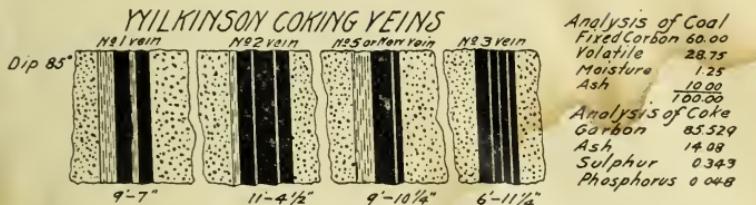
SECTIONS OF COAL SEAMS, WITH COAL ANALYSES.





SECTIONS OF COAL SEAMS WITH COAL ANALYSES.





SECTIONS OF COAL SEAMS, WITH COAL ANALYSES.



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	Willis Mine
	Yankee Mine



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